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Sediment and Radionuclide Transport in Rivers

ORIGINAL

Phase 2
Field Sampling Program for Cattaraugus and Buttermilk Creeks, New York

COMPLETED
249

Prepared by W. H. Walters, R. M. Ecker, Y. Onishi

Pacific Northwest Laboratory
Operated by
Battelle Memorial Institute

Prepared for
U.S. Nuclear Regulatory Commission

I

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Field Sampling Program for Cattaraugus and Buttermilk Creeks, New York

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ABSTRACT

A field sampling program was conducted on Cattaraugus and Buttermilk Creeks, New York during September 1978 to investigate the transport of radionuclides in surface waters as part of a continuing program to provide data for application and verification of Pacific Northwest Laboratory's (PNL) sediment and radionuclide transport model, SERATRA. Suspended sediment, bed sediment, and water samples were collected during low flow conditions over a 45 mile reach of stream channel. Radiological analysis of these samples included primarily gamma ray emitters; however, six alpha and beta-emitting radionuclides were analyzed using radiochemical methods. The Nuclear Fuel Services facilities are a possible source of two gamma-emitting radionuclides: 1) Cesium-134, and 2) Cesium-137. The principal beta-emitter found was Strontium-90. Elevated levels of both Cesium-137 and Strontium-90 were found at the sampling stations immediately downstream of the facilities. Based on downstream trends of activity levels of other radionuclides, the Nuclear Field Services facilities may also be a possible source of Plutonium-238 and 239,240, Americium-241, Curium-244, and Tritium. This field sampling effort is the second of a three phase program to collect hydrologic and radiologic data at three different flow conditions.

SUMMARY

As part of a study on sediment and radionuclide transport in rivers, Pacific Northwest Laboratory (PNL) is investigating the effect of sediment on the transport of radionuclides in Cattaraugus and Buttermilk Creeks, New York. A source of radioactivity in these creeks is the Western New York Nuclear Service Center which consists of a low-level waste disposal site and a nuclear fuel reprocessing plant. Reprocessing operations were terminated in 1972 and waste disposal was discontinued in 1975. Other sources of radioactivity include fallout from worldwide weapons testing and natural background radioactivity.

The major objective of the PNL Field Sampling Program is to provide data on sediment and radionuclide characteristics in Cattaraugus and Buttermilk Creeks to verify the use of the Sediment and Radionuclide Transport model, SERATRA, for nontidal rivers. The sampling program is composed of three phases of data collection. Phase 1 data collection was conducted during November and December 1977 (Ecker and Onishi 1979). This report covers the results of field data collection conducted during September 1978 for Phase 2.

Suspended sediment, bed sediment and water samples were collected at ten sampling stations covering approximately 45 miles of stream channel of Cattaraugus and Buttermilk Creeks and a background station on Great Valley Creek. Radiological analysis of sand, silt and clay size fractions of suspended and bed sediment, and water were performed. Results of these analyses indicate that the principal radionuclides occurring in these two water courses, with levels significantly higher than background levels, during the Phase 2 sampling program were Cesium-137 and Strontium-90. These radionuclides had significantly higher activity levels above background in the bed sediment, suspended sediment, and water samples. Other radionuclides that are possibly being released into the surface water environment by the Nuclear Fuel Services facilities are Plutonium-238 and 239,240, Americium-241, Curium-244, and Tritium.

More radionuclides were consistently found in the bed sediment as compared to suspended sediment. The fewest radionuclides were found in the

water of Buttermilk and Cattaraugus Creeks. The higher levels were found in the bed sediments for the gamma-emitters and in the suspended sediment for the alpha and beta-emitters (not including Tritium).

ACKNOWLEDGMENTS

This report summarizes the results of research conducted by the Battelle Memorial Institute's Pacific Northwest Laboratory for the U.S. Nuclear Regulatory Commission on Cattaraugus and Buttermilk Creeks, New York, during low flow conditions of September 1978. In addition to the authors of this report, significant contributions were made by R. G. Parkhurst and S. J. Phillips for field data collection. The authors also with to acknowledge the assistance of Mr. Steve Mollelo of the New York State Geological Survey in the field work and the guidance provided by Dr. Phillip R. Reed of the U.S. Nuclear Regulatory Commission.

Support work for the project was performed under subcontract to Dr. William R. Schell of the University of Washington, Laboratory of Radiation Ecology for radiological analyses.

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INTRODUCTION

This study is part of a comprehensive program by the U.S. Nuclear Regulatory Commission to investigate the importance of fluvial sediment in the transport of radionuclides in surface water systems. The study involves a three-phase field data collection program to provide radiological and hydrological data for calibration and verification of the sediment-contaminant transport model SERATRA developed by Pacific Northwest Laboratory (Onishi 1977). The Phase 2 program is the second of the field data collection efforts to provide data representative of three different flow conditions below bankfull and was conducted during September 1978. The Phase 1 program was conducted during November-December 1977 (Ecker and Onishi 1979).

The study area selected by the U.S. Nuclear Regulatory Commission is located within the watershed of Cattaraugus Creek, in rural western New York. During the 1960's the State of New York authorized the construction of a reprocessing plant near Cattaraugus Creek for spent fuel from nuclear reactors near West Valley, New York, and to operate a radioactive waste disposal site at the same location.

During the mid-1960's all burial trenches in the northern portion of the site began to fill with water after the covers were in place. This created a problem regarding burial of radioactive wastes at West Valley as the water could transport the buried radionuclides out of the trenches and into the environment. This led to the changing of burial procedures for the trenches in the southern portion of the site. The revised procedures specified new capping designs and these were required by the State in 1968 in an effort to prevent surface water from entering the trenches.

In the early 1970's small increases of radioactivity were detected in the streams adjacent to the burial site area by the New York State Department of Environmental Conservation (NYSDEC). The NYSDEC requested the U.S. Environmental Protection Agency (USEPA) to provide assistance for an on-site investigation of the problem to determine whether radionuclides were migrating from the low-level waste burial areas through the subsurface to the surrounding environment. A lithological boring study conducted in 1973 and 1974 showed tritium contamination of the surface area and of the first 10 to 15 feet of strata immediately adjacent to the burial trenches. Although the results were inconclusive, the study indicated the possibility of several sources of tritium contamination: 1) downward migration resulting from fallout from the adjacent nuclear fuel reprocessing plant, 2) spillage occurring during burial operations, and 3) lateral migration through the geologic medium directly from the burial trenches.

By 1974 trenches in the north burial site area had accumulated high levels of water while the water levels in the south trenches remained low due to the modified capping procedures. In March 1975 water in one trench in the north area seeped through the trench cap contaminating the adjacent surface area and a nearby stream. Shortly thereafter similar seepage was discovered at another trench and based on these discoveries Nuclear Fuel Services, Inc. (NFS) closed the burial site.

The NYSDEC and NFS agreed that a program to control the water levels in the north trenches was needed to prevent further seepage. A plan to pump water from the trenches that have high water levels to a radioactive waste treatment facility was approved by NYSDEC. The water was then to be diluted and released into Erdman Brook (also known as Franks Creek) under controlled conditions. This pump down and treatment procedure is unacceptable for the long-term maintenance of the burial site but may be used as a temporary measure of control of radioactive waste releases.

At the request of the U.S. Nuclear Regulatory Commission (NRC) a three-phase field data collection program was planned to provide data for the verification of a sediment-contaminated transport model, SERATRA, developed by Pacific Northwest Laboratory. Another purpose is to provide more detailed information on radionuclide activity levels in the Buttermilk-Cattaraugus Creek system. Creek bed and suspended sediment and water samples were collected for gamma-ray measurement and radiochemical analysis. The sediment samples were separated into sand, silt, and clay size classes for radiological analyses because of the different transport and physicochemical properties of each. Water discharge and water quality samples were collected at each station except the background station on Great Valley Creek. Significant trends in radionuclide activity levels and sediment transport characteristics are addressed in this report. Mathematical modeling results will be presented under separate reports.

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SITE DESCRIPTION

The Western New York Nuclear Service Center, shown in Figure 1, is located about 30 miles south of Buffalo, New York. The Center consists of a 3345-acre site in north central Cattaraugus County. The Center is situated along an elongated rolling plain with glaciated bedrock hills along the eastern, western and southern boundaries with the Buttermilk Valley along the northern boundary. All surface drainage of the Center discharges into Buttermilk Creek. At the northwest end of the property, Buttermilk Creek joins Cattaraugus Creek which flows in a westerly direction into Lake Erie, 39 miles away. Cattaraugus Creek flows in a general westerly direction through the Zoar Valley, past Gowanda, New York and the Cattaraugus Indian Reservation, and discharges into Lake Erie about 27 miles southwest of Buffalo, New York. The distance from the confluence of Buttermilk and Cattaraugus Creeks to Gowanda is about 20 creek miles and from that point about another 19 creek miles to Lake Erie.

The Franks Creek watershed which includes Erdman's Brook collects the drainage from both the low- and high-level nuclear waste burial sites. The creek joins Buttermilk Creek about 0.5 miles downstream from the burial sites. About 100 ft upstream from its confluence with Buttermilk Creek the flow passes through a 12 ft wide concrete railroad culvert. The creek is entrenched in a narrow V-shaped valley downcut through previously undisturbed glacial till containing significant amounts of very stiff, erosion resistant material. The creek channel is steep with chutes and pools and a cross-sectional width varying from 2 to 10 ft. Swampy areas can be found at certain locations along the stream course.

Buttermilk Creek has a drainage area of 29.4 mi^2. For the period of record from October 1961 to September 1968, the average discharge of Buttermilk Creek was 46.5 cfs. The extreme maximum and minimum discharges during the period of record were 3,910 cfs on 28 September 1967 and 2.11 cfs on 10 October 1963, respectively. Buttermilk Creek flows into Cattaraugus Creek about 2.25 miles downstream of the confluence with Franks Creek. The creek width under normal conditions varies from about 20 ft at the upper end to about 75 ft

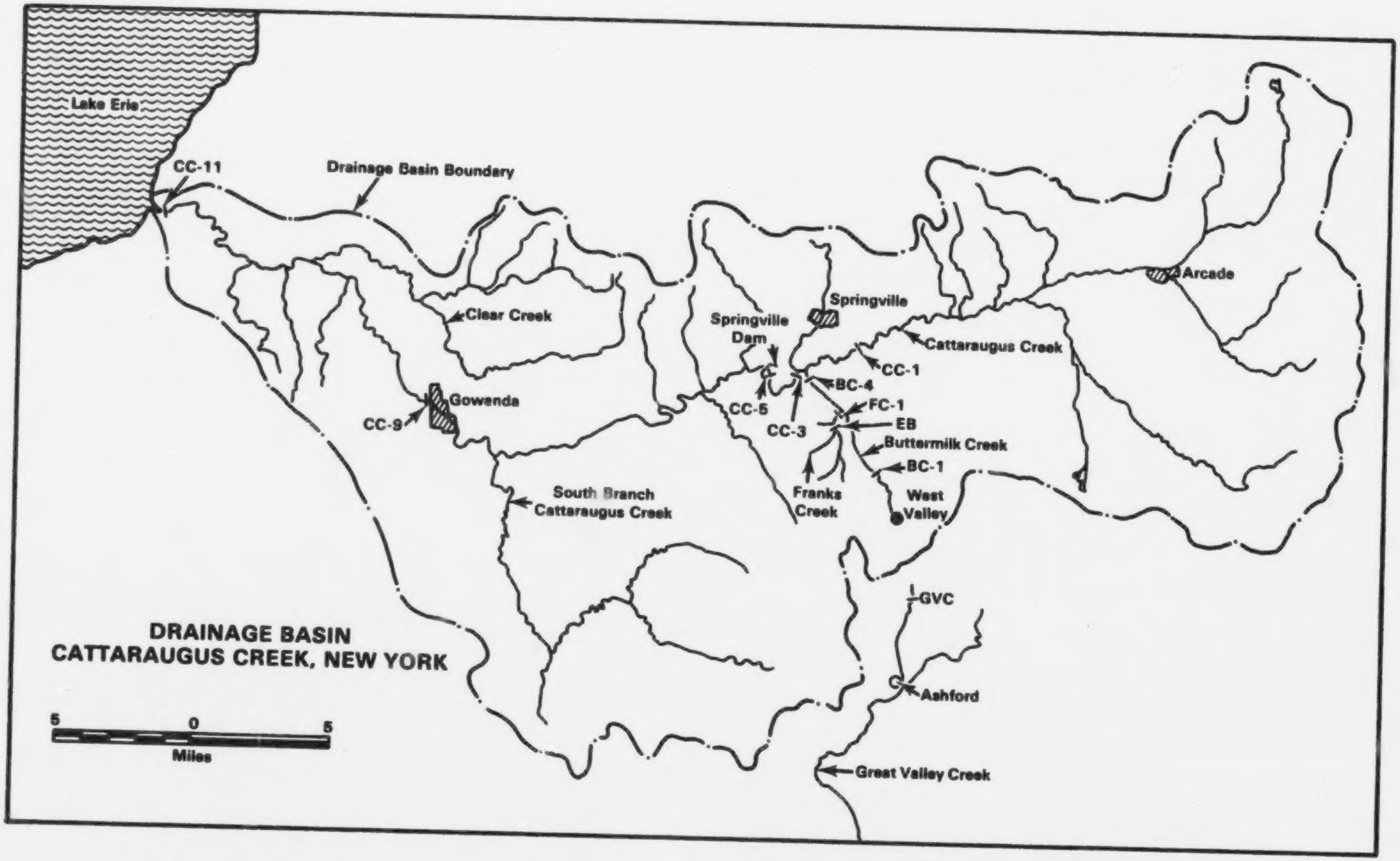
Lake Erie
CC-11
Drainage Basin Boundary
Clear Creek
Springville
Springville Dam
Arcade
Cattaraugus Creek
CC-1
BC-4
FC-1
EB
CC-5
CC-3
Gowanda
CC-9
Buttermilk Creek
BC-1
Franks Creek
West Valley
South Branch Cattaraugus Creek
GVC
Ashford
Great Valley Creek
DRAINAGE BASIN
CATTARAUGUS CREEK, NEW YORK
5
0
5
Miles

FIGURE 1. Map of the Radiological Sampling Stations on the Cattaraugus Creek System

near the confluence with Cattaraugus Creek. The channel bed is comprised of sand, gravel and cobbles with minor amounts of silt and clay size material. Water frequently overflows the channel banks leaving deposits of gravel, sand, silt, and clay on the narrow flood plain area. The flood plain varies in width from 300 to 500 ft and is bounded by high bluffs along most of its length.

A reservoir upstream of the Buttermilk Creek inflow point (Figure 2) collects runoff from a small watershed and periodically releases overflow into Buttermilk Creek. Discharge from the reservoir is regulated by a siphon spillway that maintains reservoir levels below a certain elevation. Once the siphon is primed, large quantities of water are discharged in a short period of time, producing extremely fast rising hydrographs in Buttermilk Creek during periods of relatively low flow.

Cattaraugus Creek has an estimated drainage area of 564 mi^2 at Lake Erie, 432 mi^2 at Gowanda and 218 mi^2 at the confluence with Buttermilk Creek. Based on the United States Geological Survey (USGS) gage records for Cattaraugus Creek at Gowanda, New York, the average discharge for the period of record, 1940-1976, is 731 cfs. The extreme maximum and minimum daily discharges during the period of record were 34,600 cfs on 7 March 1956, and 6 cfs, respectively, on 21 August 1941.

Peak discharges generally occur on Cattaraugus Creek in October and November, prior to the onset of winter snowfall and again in February and March as a result of snowmelt. Low discharges generally occur during the summer months of July through September when rainfall is less and again during the winter months of December and January when persistent freezing conditions exist. Cattaraugus Creek, as well as Buttermilk Creek, can be categorized as "flashy" due to their very rapid changes in discharge. Cattaraugus Creek discharges can vary upwards of 5000 cfs in a 24-hr period.

Cattaraugus Creek flows unrestricted from its headwaters to Lake Erie except for Springville Dam located about 2.5 miles downstream from the confluence of Buttermilk Creek. Springville Dam is a 20 ft high dam that creates a small reservoir extending about 0.5 miles upstream through a narrow rock gorge with walls approximately 1000 ft high. The dam and reservoir system

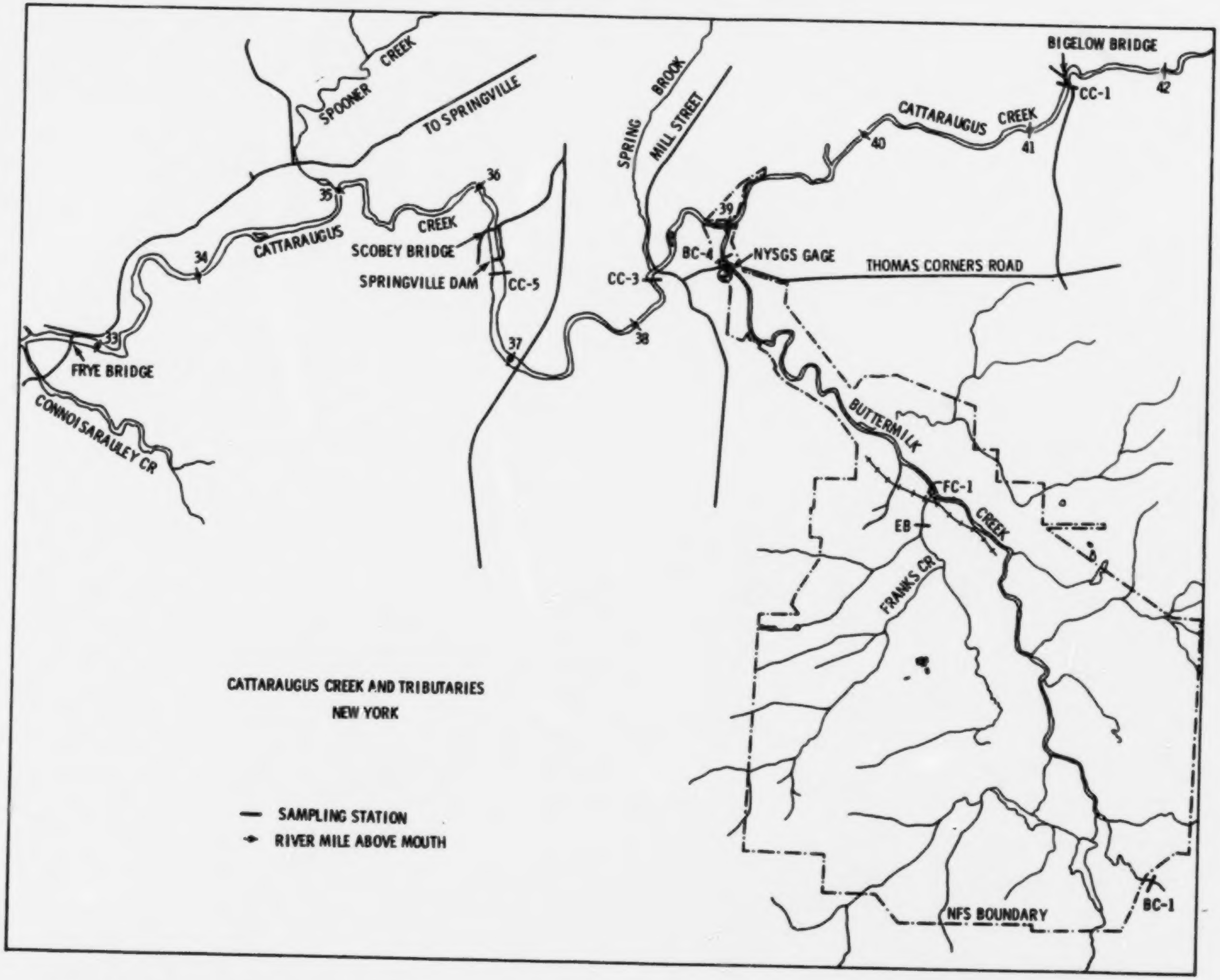
SPOONER CREEK
TO SPRINGVILLE
SPRING BROOK
MILL STREET
BIGELOW BRIDGE
CC-1
42
CATTARAUGUS CREEK
40
41
36
35
CREEK
CATTARAUGUS
34
SCOBEY BRIDGE
SPRINGVILLE DAM
CC-5
39
BC-4
NYSGS GAGE
THOMAS CORNERS ROAD
CC-3
33
FRYE BRIDGE
37
38
CONNOISARAULEY CR
BUTTERMILK CREEK
FC-1
EB
FRANKS CR.
CATTARAUGUS CREEK AND TRIBUTARIES
NEW YORK
SAMPLING STATION
RIVER MILE ABOVE MOUTH
NFS BOUNDARY
BC-1

FIGURE 2. Sampling Stations Located in Close Proximity to the West Valley Facilities for the Phase 2 Program

provides water supply for a run-of-the-river hydroelectric plant operated by the village of Springville. The plant's generators supply about 20% of the electric power requirements of the village.

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PHASE 2 SAMPLING PROGRAM

The Phase 2 data collection program was intended to gather radiologic and hydrologic information under steady low flow conditions. The field work was conducted from September 20 to September 26 1978 during a time when the Cattaraugus Creek system is normally at low flow.

SAMPLING PROCEDURES

Because of the low radioactivity levels found in the water of Cattaraugus and Buttermilk Creeks, certain modifications have been made to the sampling procedures used in Phase 1. The water processed for radiological analysis of suspended sediment and water was increased from 80 gallons to 400 gallons. The separation of suspended sediment from water was included in the field sampling to eliminate the need of transporting large volumes of water. The in-stream sampling of water and suspended sediment was accomplished by utilizing a large volume water sampler developed by Battelle, Pacific Northwest Laboratories. The sampling apparatus, including the Large Volume Water Sampler (LVWS), is shown in Figure 3. A discussion of the principle of the LVWS and the analysis procedure can be found in Appendix A. Basically the method allows the processing of a large volume of water in the field within a relatively short period of time that eliminates the necessity of separating the suspended sediment and other particulates from the water in the laboratory. The procedure concentrates the quantities of suspended sediment and radionuclide in the field providing a larger sample for laboratory analysis. Because of the possibility of a significant suspended sediment load and the modeling requirement that the sediment be separated into three classes (clay, silt, and sand) the water sampling procedure has been divided into two phases: 1) suspended sediment or particulate, and 2) dissolved (including colloidal).

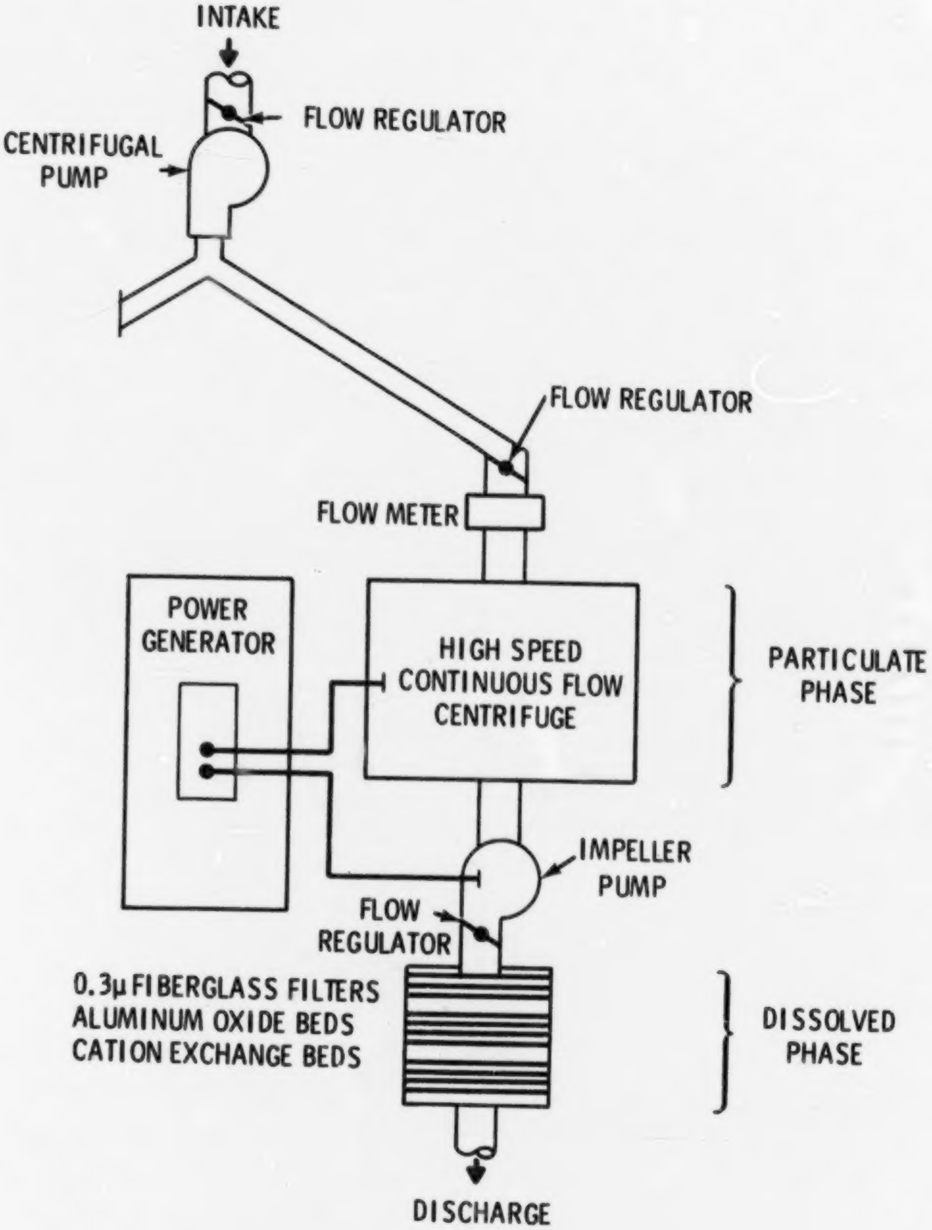
INTAKE
FLOW REGULATOR
CENTRIFUGAL PUMP
FLOW REGULATOR
FLOW METER
POWER GENERATOR
HIGH SPEED CONTINUOUS FLOW CENTRIFUGE
PARTICULATE PHASE
IMPELLER PUMP
FLOW REGULATOR
0.3μ FIBERGLASS FILTERS
ALUMINUM OXIDE BEDS
CATION EXCHANGE BEDS
DISSOLVED PHASE
DISCHARGE

FIGURE 3. Phase 2 Sampling Apparatus

Water and Suspended Sediment Sampling

The suspended sediment phase used a high-speed continuous flow centrifuge to separate the suspended sediment from the water. A Westfalia Model OTA 7-00-066 Clarifuge was used which has the capability of processing about 300 gallons of water per hour at about 9000 rpm. The sediment retained in the centrifuge was later partitioned into sand, silt, and clay fractions by further centrifuging in the laboratory.

The dissolved phase used a set of three 0.3 μ fiberglass filters to trap any remaining particulate material not removed by the centrifuge. The filters were placed directly in front of the sorption beds in the BLVWS column. The particulate free water then was passed through a series of three aluminum oxide (Al_2O_3) beds and three cation exchange beds to capture the colloidal and dissolved radionuclide. Water samples were taken at the discharge end of the system for tritium analysis.

Bed Sediment Sampling

Samples of bed sediment were collected independently by using a scoop for grab sampling at each sampling station. These samples were separated into sand, silt, and clay in the laboratory before radiological analyses were performed. Bed sediment samples were collected in Lake Erie just outshore from the mouth of Cattaraugus Creek. The samples were collected in tubes which were pushed by hand into the lake bed and capped immediately after withdrawal.

Water Quality Characteristics

The water quality characteristics measured during the sampling program were water temperature, pH and hardness. Water temperature is required to calculate viscosity for the SERATRA code. The pH and hardness are used in evaluating the adsorption and desorption coefficients.

Water Velocity Measurements

The water velocity was measured for discharge computations at each sampling station except the background station on Great Valley Creek and the bed material sampling stations at Erdmans Brook and Lake Erie. Velocity measurements were taken at the 0.2 and 0.8 depths if the total depth was >2.5 ft.

For depths, <2.5 ft one measurement was taken at the 0.6 depth. The measurements were taken along the sampling station transverse cross-section at distance intervals determined in the field. The measurements were obtained by wading except at Springville Reservoir where the measurements were made from a boat with the current meter attached to an extended wading rod.

Cross-Section Geometry

The channel cross-section was surveyed for each sampling station where velocity measurements were made using a surveyors level and rod. A cable tagline and steel tape were used to determine distances between the cross-section elevations. The elevations were tied into a temporary benchmark.

SAMPLING STATIONS

The use of the LVWS sampling methodology sacrificed mobility since the equipment required mounting on the bed of a truck. This precluded sampling at two of the Phase 1 stations because of inaccessibility. The stations omitted were: 1) BC-2 on Buttermilk Creek located about 1200 ft downstream from the confluence with Franks Creek, and 2) BC-3 at Bond Road Bridge on Buttermilk Creek. However, four bed core samples were collected from Lake Erie near the mouth of Cattaraugus Creek and one additional bed sample from Erdmans Brook (Franks Creek watershed). The cross-sectional plots of the sampling stations showing the water and sediment sampling points can be found in Appendix B. The individual stations are briefly described in the following paragraphs.

Great Valley Creek (GVC)

This station is located about 5 miles south of BC-1 and about 2 miles north of the town of Ashford. The sampling point is in the upper watershed area of Great Valley Creek which is a tributary of the Allegheny River. The station provides a sampling point in a watershed not a part of the Cattaraugus Creek system but near the NFS facilities and is considered a background station. No cross-section was surveyed.

Buttermilk Creek-Station 1 (BC-1)

This station is upstream of the mouth of Franks Creek and therefore upstream of the outflow from the NFS facilities. It is a background station for Buttermilk Creek. The stream cross-section is located about 40 ft upstream of the Fox Valley Road bridge and is plotted in Figure B.1. The suspended sediment sample was taken at about mid-depth of the cross-section sampling point.

Franks Creek-Station 1 (FC-1)

The NFS facilities are located within the Franks Creek watershed and the creek is the main uncontrolled outflow point from the facilities area. There is another outflow point just upstream at a siphon spillway of a small reservoir within the facilities area that periodically releases to Buttermilk Creek. The sampling station cross-section (Figure B.2) is located at the Baltimore and Ohio Railroad culvert outlet which is about 100 ft upstream of the confluence with Buttermilk Creek. This creek is the only surface water outflow point for the NFS facilities monitored in this study.

Erdmans Brook (EB)

Erdmans Brook, sometimes referred to as Franks Creek, is defined as a small tributary to Franks Creek as shown in the map of Figure 2. Only bed material samples were taken at this location and provide a comparison of radioactivity levels with bed material samples at other locations. No cross-section survey was made of the sampling station.

Buttermilk Creek-Station 4 (BC-4)

The station at BC-4 is an intermediate sampling station between the Franks Creek outflow point and Cattaraugus Creek. The cross-section (Figure B.3) is located about 100 ft downstream from the Thomas Corners Road bridge and 0.2 miles upstream from Cattaraugus Creek.

Cattaraugus Creek-Station 1 (CC-1)

This station is located directly beneath Bigelow Bridge (Elk Street Bridge) and is the upstream inflow point of the Cattaraugus Creek study area. The station also provides background data for Cattaraugus Creek. The cross-sectional sampling point was positioned next to the right bank bridge abutment as shown in Figure B.4.

Cattaraugus Creek-Station 3 (CC-3)

The stream cross-section for this station is located about 100 ft downstream of Felton Bridge (Mill Street Bridge). Samples were taken at three transverse points in the cross-section as shown in Figure B.5. Stations CC-3/1 and CC-3/2 were sampled at mid-depth. Station CC-3/1 was sampled at two points in the vertical. This is the first sampling station downstream of the Buttermilk Creek confluence and upstream of Springville Reservoir.

Cattaraugus Creek-Station 5 (CC-5)

This station is located in Springville Reservoir about 500-ft upstream of the spillway. Samples were taken at three points along the cross-section as shown in Figure B.6. Stations CC-5/1 and CC-5/3 were sampled at a vertical distance 5 ft above the reservoir bed at approximately mid-depth. The intermediate station, CC-5/2, was sampled at three points in the vertical. The bed sediment samples taken at CC-5 may give some indication if radionuclides are effectively trapped by the reservoir.

Cattaraugus Creek-Station 9 (CC-9)

This station is located about 21 miles downstream from Springville Dam and reservoir at Gowanda. The stream cross-section is located about 150 ft downstream of Taylor Hollow Road bridge. The station is about 15 miles upstream from Lake Erie and is an intermediate point between Springville Dam and Lake Erie. Samples were taken at one cross-sectional point at about mid-depth as shown in Figure B.7.

Cattaraugus Creek-Station 11 (CC-11)

This station is located underneath the New York Central Railroad bridge about 4000 ft upstream from the mouth of Cattaraugus Creek at Lake Erie. Samples were taken at one cross-sectional station at two points in the vertical as shown in Figure B.8.

Lake Erie Station

Core samples of bed sediment were taken at four sampling points outshore from the mouth of the Cattaraugus Creek. All four points are located along a straight line parallel to the shoreline at about one-half mile intervals. The line is about three-fourths of a mile from the shoreline. The sampling points are numbered one through four from west to east with point 3 directly outshore from the mouth of Cattaraugus Creek.

STREAMFLOW CONDITIONS DURING SAMPLING

The only permanent stream gaging station on the Cattaraugus Creek system is located at Gowanda, New York about 16.5 creek miles upstream from Lake Erie. Daily average discharges for the period from September 15 through September 28, 1978 were obtained from the U.S. Geological Survey office at Ithaca, New York. The discharge values are shown in Table 1 and the discharge hydrograph for the time period is plotted in Figure 4. The hydrograph shows that the sampling took place during the recession curve where the runoff from an earlier rainfall event was being withdrawn from basin storage. The flow at Gowanda during the sampling period varied from 420 cfs on September 20 to 180 cfs on September 26, 1978. Flows approaching base flow conditions at Gowanda existed for the last two or three days of the sampling period. The average daily discharge of 731 cfs for Cattaraugus Creek at Gowanda indicates that very low flow conditions existed during most of the sampling period.

Streamflow velocities were measured at each sampling station cross-section as part of the data collection process. The water discharge and mean velocity at each station were calculated and is listed in Table 2. The maximum water depth at each sampling point is also listed.

Water temperature, dissolved oxygen, and water hardness measurements were taken at sampling stations where water and suspended sediment samples were collected except at the Great Valley Creek background station. The water temperature was measured with an in-situ temperature probe.

Dissolved oxygen was measured with a Yellow Spring Instrument Co. meter, model 51A. The probe used has a built-in stirrer and measurements were taken with the sample in a standard BOD bottle. Prior to each measurement, the instrument was calibrated over staurated water in a BOD bottle.

Total organic carbon (TOC) samples were collected in one ounce polyethylene bottles and acidified to pH 2 in the field. Samples were analyzed using

TABLE 1. Average Daily Discharge for Cattaraugus Creek at Gowanda, New York for September 15-28, 1978

Date	Discharge (cfs)
September 15	218
16	385
17	392
18	554
19	832
20	420
21	276
22	229
23	201
24	182
25	181
26	180
27	174
28	167

a Beckman Model 915 Total Organic Carbon Analyzer. Standard organic carbon solutions were prepared according to Standard Methods, No. 505.

Water hardness was measured in the field utilizing the procedure described in Standard Methods, No. 309B using commercial reagents manufactured by Betz Laboratories. Standard EDTA solutions were prepared from standard ampoules obtained from Baker Chemical Company. The results are reported as mg/l $CaCO_3$.

BEST DOCUMENT AVAILABLE

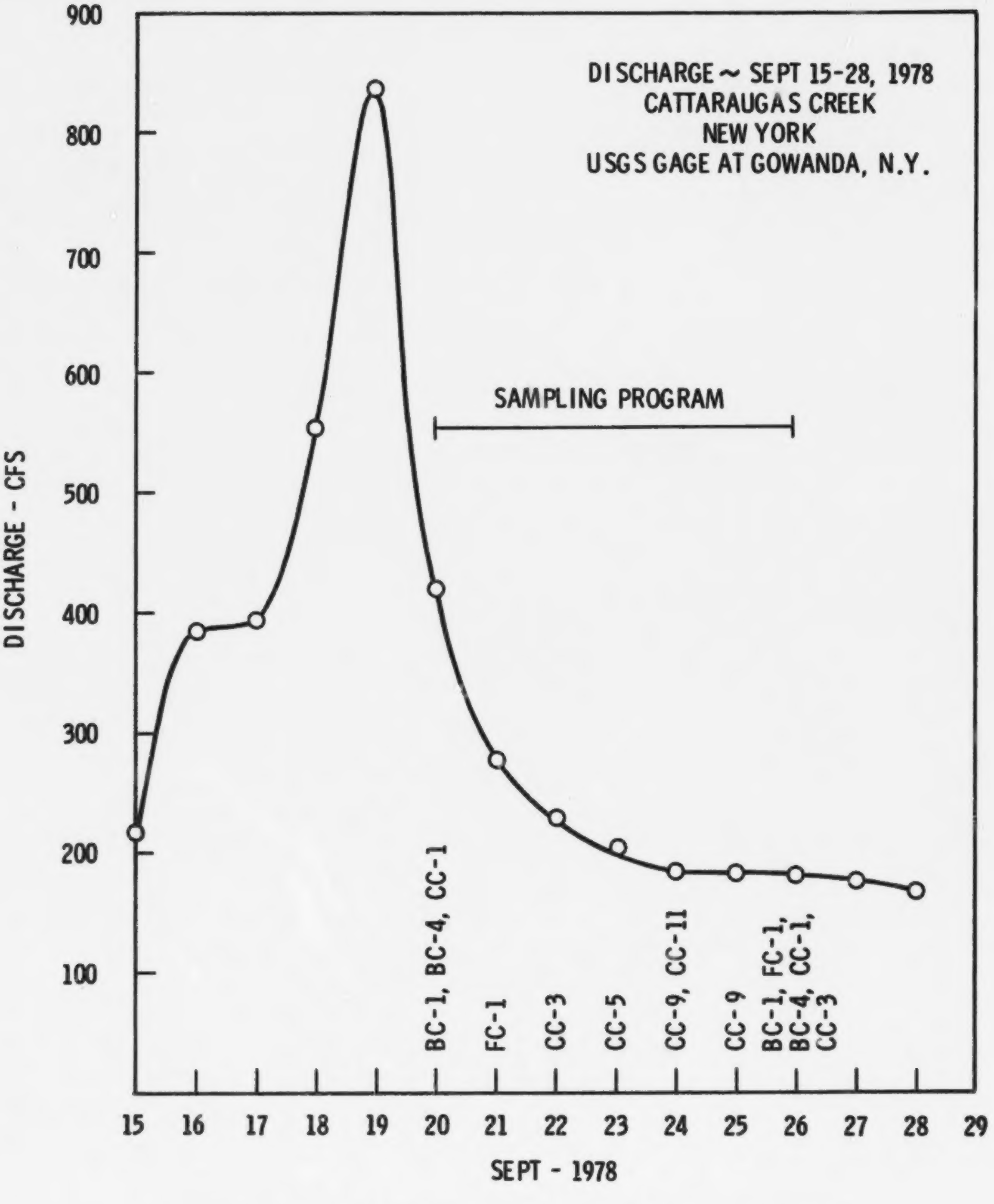

FIGURE 4. Discharge Hydrograph for Cattaraugus Creek at Gowanda, New York (September 15-28, 1978).

TABLE 2. Summary of Sampling Station Water Discharge Data and Sampling Point Depth

Transect	Date	Maximum Depth (ft)	Mean Velocity (ft/sec)	Water Discharge (cfs)
FC-1 Franks Creek	9/21/78	0.81	0.26	2.2
BC-1 Fox Valley Road	9/20/78	0.48	1.98	7.2
BC-4 Thomas Corners Bridge	9/20/78	1.67	1.43	20.3
CC-1 Bigelow Bridge	9/20/78	3.25	1.23	223.9
CC-3 Felton Bridge	9/22/78		1.56	149.2
Station 1		1.77		
Station 2		0.79		
Station 3		0.95		
CC-5 Springville Res.	9/23/78		0.14	192.2
Station 1		10.73		
Station 2		11.25		
Station 3		10.9		
CC-9 Gowanda	9/24/78	3.29	0.51	146.4
CC-11 Mouth Cattaraugus	9/24/78	15.16	0.14	297.1

LABORATORY PROCEDURES FOR SEDIMENT SAMPLES

The suspended sediment samples collected by centrifugation and the bed sediment grab samples were returned to Pacific Northwest Laboratory, for separation into sand, silt, and clay fractions. The separated samples were then shipped to the University of Washington, Laboratory of Radiation Ecology for radiological analysis.

SUSPENDED SEDIMENT

The suspended sediment collected from the centrifuge was separated into sand, silt, and clay using the procedure outlined in "Soil Chemical Analysis" (Jackson 1956). The sediment samples were initially wet-sieved through a No. 200 U.S. Standard sieve. The material retained on the sieve was dried, weighed, and reported as sand ($>74\ \mu$). The material passing through the sieve was dispersed using an electric mixer (ASTM stirring Apparatus A) and centrifuged at 750 rpm for 3.3 min. The material remaining after centrifugation was decanted, evaporated to dryness, and weighed. These fractions were reported as clay ($<4\ \mu$). The material remaining in the centrifuge cups after decantation of the suspended clay was dried, weighed, and reported as silt ($4\ \mu <$ silt $< 74\ \mu$).

BED SEDIMENT

The bed sediment samples were first dried in the oven at 103°F and then sieved on a Ro Tap Shaker. The material remaining on the No. 10 sieve (>2 mm) classified as very fine gravel or larger was weighed and discarded since radiological analysis was to be performed only on sand sizes or smaller. The sand sizes were separated into coarse medium, and fine sand according to the following sieves as shown in Table 3.

The portion of the sample passing the No. 200 sieve ($<74\ \mu$) was allowed to soak in distilled water overnight and separated into silt and clay fractions by the same method used for the suspended sediment.

TABLE 3. Sieve Breakdown for Laboratory Analysis of Sand-Sized Material

Sieve No.	Size in Millimeters	Class
>10	>2.00	Very fine gravel or larger
10 x 40	2.00 - 0.42	Coarse Sand
40 x 120	0.42 - 0.125	Medium Sand
120 x 200	0.125 - 0.074	Fine Sand

RADIOLOGICAL ANALYSIS

The separated sediment samples, filters, aluminum oxide and resin beds, and water samples were sent to the Laboratory of Radiation Ecology (LRE) at the University of Washington for radiological analysis. Both gamma-ray spectrometry and radiochemical separation procedures were required. All but six of the radionuclides were analyzed by gamma-ray spectrometry. The radionuclides of Tritium, Strontium-90, Plutonium-238, Plutonium-239,240, Americium-241, and Curium-244 were analyzed for activity levels radiochemically. A listing of the radionuclides found in the samples is presented in Table 4. The laboratory procedures used by the University of Washington are described in Appendix C.

The results of he radiological analysis can be found in Appendix D. The tables are organized with respect to each sampling station. Tables D.1 and D.2 represent the activity levels of radionuclides in bed sediment determined by gamma-ray spectrometry for the Buttermilk-Cattaraugus stations and Lake Erie, respectively. The activity levels of the alpha and beta-emitting radionuclides in bed sediment as determined by radiochemical separation methods are presented in Tables D.3 and D.4 for the Buttermilk-Cattaraugus Creek stations and Lake Erie, respectively. The activity levels of radionuclides associated with suspended sediment from the centrifuge are presented in Table D.5 (gamma-emitters) and Table D.6 (alpha and beta emitters). The activity levels for both bed and suspended sediment samples are reported in pico Curies per gram (pCi/g) for sand, silt, and clay. The composite values were computed using weighted averages based on the percent dry weight of the total in-situ sample. These weights are listed as "Sample wt., Field (g)" for each sediment class. The other weight listed as "Sample wt., Analysis (g)" is the dry weight used in the analysis by the University of Washington.

The activity levels of dissolved radionuclides in the waters of the Buttermilk and Cattaraugus Creek system are presented in Table D.7 (gamma-emitters) and Table D.8 (alpha and beta-emitters). The activity levels are reported as pico Curies per liter (pCi/l). The arrangement of the data

TABLE 4. Radionuclides Found in the Water and Sediment of the Cattaraugus Creek Station. Isotope data from Public Health Service (1970)

Isotope	Symbol	Atomic No.	Half-Life	Major Radiations
1. Tritium	H-3 or T	1	12.262Y	β^-
2. Beryllium-7	Be-7	4	53.6d	γ
3. Potassium-40	K-40	19	1.26x10^9H	β^-, β^+, γ
4. Chromium-51	Cr-51	24	27.8d	γ, e^-
5. Manganese-54	Mn-54	25	303d	γ, e^-
6. Cobalt-60	Co-60	27	5.263Y	β^-, γ
7. Zinc-65	Zn-65	30	245d	β^+, e^-, γ
8. Strontium-90	Sr-90	38	27.7Y	β^-
9. Niobium-95	Nb-95	41	35d	β^-, γ
10. Ruthenium-103	Ru-103	44	39.6d	β^-, γ
11. Ruthenium-106	Ru-106	44	367d	β^-, daughter radiations from 30S Rn-106
12. Rhodium-101	Rh-101	45	3.0Y	γ, e^-
13. Rhodium-102	Rh-102	45	2.9Y	γ
14. Antimony-125	Sb-125	51	2.71Y	β^-, e^-, γ
15. Cesium-134	Cs-134	55	2.046Y	β^-, γ
16. Cesium-137	Cs-137	55	30.0Y	β^-, d^-, γ
17. Cerium-141	Ce-141	58	32.5d	β^-, e^-, γ
18. Cerium-144	Ce-144	58	284d	β^-, e^-, γ
19. Europium-152	Eu-152	63	12.7Y	β^-, β^+, e^-, γ
20. Europium-155	Eu-155	63	1.811Y	β^-, e^-, γ
21. Lead-210	Pb-210	82	20.4Y	α, β^-, e^-, γ
22. Bismuth-207	Bi-207	83	30.2Y	e^-, γ
23. Radium-226	Ra-226	88	1602Y	α, e^-, γ
24. Radium-228	Ra-228	88	6.7H	γ^-, e^-, daughter radiations from Ac-228, Th-228, Ra-224, etc.
25. Thorium-228	Th-228	90	1.910Y	α, γ, e^-
26. Thorium-232	Th-232	90	1.41x1010Y	α, γ, e^-
27. Uranium-235	U-235	92	7.1x10^8Y	α, γ
28. Uranium-238	U-238	92	4.51x10^9Y	α, γ, e^-
29. Plutonium-238	Pu-238	94	86.4Y	α, γ, e^-
30. Plutonium-239, 240	Pu-239, 240	94	24,390Y 6580Y	α, γ, e^-
31. Americium-241	Am-241	95	458Y	α, e^-, γ
32. Curium-244	Cm-244	96	17.6Y	α, γ, e^-

α = Alpha-particle emission
β^- = Negative Beta-particle (negatron) emission
β^+ = Positive Beta-particle (positron) emission
γ = Gamma-ray emissions
e^- = electron emissions

columns are numbered in the direction of flow through the large volume water sampler. Because the activity levels of the detected radionuclides on the sorption beds did not consistently decrease in the direction of flow, the efficiency of the LVWS could not be calculated except for Americium-241. The totals shown in the last two columns of Tables D.7 and D.8 are only minimum values of the radionuclides determined by summing the activity levels on the sorption beds including Americium-241. Comparison is made with the total minimum values and those determined by sorption bed efficiency calculations in the "Results" section. The analysis results for Tritium levels in the water, as performed on individual water samples, are reported in Table D.9.

The initial radiological results received from the University of Washington did not list the minimum detectable limits for radionuclides not detected during analysis. These tables contain blanks where activity levels were below detection. Where activity levels of radionuclides were detected, the values in parentheses represent two standard deviations of the propogated counting error at these particular stations.

Prior to completing the analysis of Phase 2 samples, the University of Washington revised their counting technique. The remaining samples were analyzed using a new computer based analytical system consisting of a Nuclear Data 6620 unit. This system consists of two 7.5 ℓ Ge(Li) detectors (old), one 25 ℓ Ge(Li) detector (new), amplifiers and analog to digital converters which transfer the pulse height information into the N.D. 6620 system where it is sorted on the disc memory. The computer was programmed to peak search, peak integrate, background subtract and to give the minimum detectabe limits for the radionuclides analyzed in the samples. The minimum detectable limits determined by this method are shown as "less than" values in the data columns. The values in parentheses represent one standard deviation of propagated counting error for data tables presented in this manner.

RESULTS

WATER QUALITY CHARACTERISTICS

The results of the water quality sampling during the Phase 2 field program are summarized in Table 5. The water temperatures on Cattaraugus Creek varied from a high of 24.0°C on September 20 to a low of 14.1°C on September 24, 1978. Two temperature measurements were obtained on Buttermilk Creek on September 20 of 16.5°C (BC-1) and 20.0°C (BC-4). The lowest temperature of 16.5°C was recorded upstream of the NFS facilities.

The highest value for water hardness of 8.5 mg/l $CaCO_3$ was recorded at Franks Creek at the outflow point from the NFS facilities. The lowest value of 4.7 mg/l $CaCO_3$ was recorded at BC-4 on Buttermilk Creek about 2 miles downstream from Franks Creek. The hardness at Station CC-3 about 2.5 miles upstream of Springville dam varied from 5.7 to 7.85 mg/l $CaCO_3$ across the channel cross-section. The water hardness at the sampling station, CC-5 in Springville Reservoir was very uniform varying from 6.6 to 6.8 mg/l $CaCO_3$ at three sampling points in the cross-section. Total organic carbon (TOC) varied from 12.0 to 5.5 ppm with the highest measurement recorded at Station FC-1 on Franks Creek. Dissolved oxygen (D.O.) varied from 8.4 to 10.2 mg/l with the higher values of 10.0 and 10.2 mg/l measured at the two downstream Stations CC-9 and CC-11, respectively.

SEDIMENT CHARACTERISTICS

Suspended Sediment

Suspended sediment samples were collected by two different methods during the Phase 2 program. Samples were taken from the centrifuge during the combined water and sediment sampling for radiological analysis. The samples were separated into sand, silt, and clay by the procedures described in the section "Laboratory Procedures for Sediment Samples." The results are listed in Table 6. Due to the extreme low flow, the precent sand was very low. The bulk of all suspended sediment samples was composed of the silt and clay sized classes.

TABLE 5. Summary of Water Quality Characteristics

Station	Date	Water Temp. °C	Hardness mg/l CaCO3	T.O.C. ppm	D.O. mg/l
FC-1	9/21/78		8.5	12.0	
BC-1	9/20/78	16.5	5.3	9.0	9.8
BC-4	9/20/78	20.0	4.7	8.5	8.4
CC-1	9/20/8	24.0	5.7	5.5	9.3
CC-3/1		18.0	6.9	7.5	9.6
CC-3/2		18.0	7.85	9.0	9.7
CC-3/3		18.0	5.7	9.0	9.6
CC-5/1	9/23/78	17.9	6.7		9.7
CC-5/2		17.4	6.8		9.7
CC-5/3		19.0	6.6		9.6
CC-9	9/24/78	14.1	6.7	9.5	10.2
CC-11	9/24/78	17.5	5.3	8.0	10.0

Silt is the most predominant class of sediment having a range of percentages from 62.65% at the background station GVC to a maximum percentage of 90.61 at CC-5/3 in Springville Reservoir. The lowest percentages of sand were found in Springville Reservoir as would be expected because of the backwater effect

TABLE 6. Suspended Sediment Samples

Station	Weight in Grams and Percent Weight per Sediment Class			
	Sand	Silt	Clay	Total
GVC (Background)	0.170	4.582	2.562	7.314
	2.32%	62.65%	35.03%	
BC-1	0.575	10.870	2.283	18.728
	4.19%	79.18%	16.63%	
FC-1	0.133	8.744	3.432	12.309
	1.08%	71.04%	27.88%	
BC-4	0.544	59.562	17.6780	77.786
	0.70%	76.57%	22.73%	
CC-1	0.554	13.997	3.433	17.984
	3.08%	77.83%	19.09%	
CC-3/1 (top)	0.087	6.924	1.803	8.814
	0.99%	78.56%	20.46%	
CC-3/1 (bottom)	0.173	10.148	4.466	14.787
	1.17%	68.63%	30.20%	
CC-3/2	0.342	19.309	5.545	25.196
	1.36%	76.64%	22.01%	
CC-3/3	0.204	15.270	2.104	17.578
	1.16%	86.87%	11.97%	
CC-5/1	0.021	34.445	4.142	38.608
	0.05%	89.22%	10.73%	
CC-5/2 (top)	0.024	15.990	3.041	19.208
	0.12%	83.25%	16.63%	
CC-5/2 (mid)	0.030	20.708	4.043	31.854
	0.09%	87.21%	12.69%	
CC-5/2 (bottom)	0.002	44.401	4.827	49.248
	0.04%	90.16%	9.80%	
CC-5/3	0.026	20.708	2.119	22.853
	0.11%	90.61%	9.27%	
CC-9	0.691	24.308	8.277	33.276
	2.08%	73.05%	24.87%	
CC-11 (top)	0.073	12.869	3.041	15.483
	0.46%	80.52%	19.03%	
CC-11 (bottom)	0.095	20.456	3.213	23.764
	0.4%	86.08%	13.52%	

of the dam and the reduced transport velocities. The percentages for Station CC-5 varied from 0.12% to 0.04%. The higher percentages of sand are found at the upstream samping stations such as BC-1 (4.19%), CC-1 (3.08%), and GVC (2.32%) where the channel gradients are steeper and flow velocities were higher during the Phase 2 program.

Suspended sediment samples were obtained in one-liter bottles so the actual silt and clay concentrations could be determined. Because sand concentrations were very low, depth-integrated samples were not obtained. Silt and clay concentrations can be determined by one point sample since they are for the most part distributed uniformly over the cross-section. These samples were analyzed by filtration methods in the laboratory to determine total suspended sediment at each sampling point. Because of the uniformity of the silt and clay concentration in the cross-section, approximate concentrations in milligrams per liter (mg/l) can be determined by using the percentages of silt and clay calculated from the centrifuged samples. Since the concentration of sand particles in the water column increases with depth, the percentages of sand are valid only for the points in the vertical at which the samples were taken. The total suspended sediment concentrations for each sampling station determined in the laboratory and the calculated concentrations of sand, silt, and clay are shown in Table 7.

The highest concentrations of clay (67.02 mg/l) and silt (170.78 mg/l) occurred in Franks Creek (FC-1). The high values sampled at CC-11 for the bottom sampling point are due to disturbance of the bed by the divers during sample collection and is not considered a valid concentration. The differences between BC-1 and BC-4 which are the upstream and downstream sampling stations, respectively, from FC-1 reflects the added suspended sediment bed from Franks Creek. The Cattaraugus Creek stations from CC-1 through CC-5 at Springville Reservoir indicate a very uniform distribution of clay-sized particles. Silt concentrations in Cattaraugus Creek have more variation, however, they are still less than one-half the value of the BC-4 concentration in Buttermilk Creek. The near-uniformity of the clay particles is most likely due to the lack of significant tributary inflow and overland runoff upstream of Springville Dam during the sampling period.

TABLE 7. Suspended Sediment Concentrations

Station	Concentration in mg/l			
	Sand	Silt	Clay	Total
BC-1	0.63	11.92	2.50	15.06
FC-1	2.60	170.78	67.02	240.4
BC-4	0.42	45.65	13.55	59.62
CC-1	0.48	12.13	2.97	15.58
CC-3/1 Top	0.10	8.03	2.09	10.22
CC-3/1 Bottom	0.11	6.26	2.75	9.12
CC-3/2	0.15	8.37	2.40	10.92
CC-3/3	o.21	15.90	2.19	18.30
CC-5/1	0.01	20.61	2.48	23.10
CC-5/2 Top	0.02	10.81	2.16	12.98
CC-5/2 Mid	0.01	14.11	2.05	16.18
CC-5/2 Bottom	0.01	20.39	2.22	22.62
CC-5/3	0.01	11.45	1.17	12.64
CC-9	0.57	20.16	6.86	27.6
CC-11 Top	0.02	3.49	0.83	4.34
CC-11 Bottom(a)	2.98	641.64	100.78	745.4

(a) Bed disturbed by divers during sampling

Bed Sediment

The result of the size distribution analysis for bed sediment is presented in Table 8. The sampling stations located in the main channels of Buttermilk and Cattaraugus Creeks yielded very high percentages of sand and gravel. These were the stations at BC-1, BC-4, CC-3/1, CC-3/2, CC-3/3, and CC-9. Because of the unimpeded streamflow at these locations, the finer material does not settle except at extreme low flow and then only in limited quantities.

The Erdmans Brook station (EB) has a percent weight of silt on the same order of magnitude as sand and gravel. The percent clay is also much higher than at other free stream flow stations. The higher percentages of silt and

TABLE 8. Bed Sediment Samples

Station	Weight in Grams and Percent Weight per Sediment Class				
	Gravel	Sand	Silt	Clay	Total
BC-1	3683.0 66.93%	1732.5 31.48	82.5 1.50%	4.94 0.09%	5502.94
EB	584.0 35.56%	443.5 27.0%	532.0 32.39%	83.0 5.05%	1642.5
FC-1	501.0 21.86%	1207.0 52.66%	531.0 23.17%	53.0 2.31%	2292.0
BC-4	5242.0 73.09%	1627.5 22.69%	287.0 4.0%	15.0 0.21%	7171.5
CC-1	4054.0 84.8%	665.0 13.91%	59.8 1.25%	1.75 0.04%	4780.55
CC-3/1	867.0 40.4%	833.0 38.32%	437.0 20.36%	9.0 0.42%	2146.0
CC-3/2	4267.0 84.08%	771.5 15.20%	35.9 0.71%	0.77 0.02%	5075.17
CC-3/3	4776.0 71.82%	1554.0 23.37%	292.0 4.39%	28.2 0.42%	6650.2
CC-5/1	18.2 4.26%	3.61 0.85%	364.5 85.4%	40.5 9.49%	426.81
CC-5/2	3.2 0.48%	5.91 0.89%	592.0 88.74%	66.0 9.89%	667.11
CC-5/3	0.34 0.05%	2.29 0.31%	648.0 86.56%	98.0 13.09%	748.63
CC-9	1905.0 80.09%	438.7 18.44%	34.7 1.46%	0.3 0.01%	2378.7
CC-11	99.0 14.19%	52.49 7.53%	502.0 71.97%	44.0 6.31%	697.49

clay are due to the series of small pools that form during low flow conditions and trap more of the silt and clay sizes. Erdmans Brook also flows through swamp-like reaches and the banklines are composed primarily of clay and silt.

The station at Franks Creek (FC-1) shows the same trend as that at Erdmans Brook. This is because of the very flat gradient of the railroad culvert invert where flow velocity is very small during low flows and allows a percentage of the finer sediment to settle out.

The stations at Springville Reservoir, CC-5/1, CC-5/2, and CC-5/3 plus the station CC-11 at the mouth of Buttermilk Creek are in slack water areas where the silt and clay particles can easily settle to the bed. The Station CC-11 is located within the backwater area of Lake Erie where the flow behavior is much like that of a reservoir. Both of these station locations have extremely high percentages of silt and clay in the bed material.

RADIOLOGICAL ANALYSIS

The results of the laboratory analysis of the various samples indicated that certain radionuclides were predominant in the Buttermilk-Cattaraugus Creek system. These particular radionuclides were consistently detected at most all sampling stations. Gamma analysis results indicate that the radionuclides Potassium-40, Cesium-134 and 137, Radium-226, Thorium-228 and 232, and Uranium 235 and 238 were present at all stations. The radiochemical analysis of Strontium-90, Plutonium 238 and 239,240, Americium-241, and Curium-244 indicated their presence at practically all the stations analyzed by these procedures. A summary of radionuclide presence with respect to the sampling stations is provided in Table 9.

At Erdmans Brook (EB) and Lake Erie, only bed sediment was sampled. The samples from Erdmans Brook were taken to determine radionuclide activity levels in the upper reaches of the Franks Creek system nearer the burial grounds. The Lake Erie samples were taken for purposes of activity level comparison and to determine radionuclide presence in Lake Erie sediments.

Sedimentation Processes

The sediment transported by a stream can have a wide range of sizes, shapes, densities, and chemical properties. Particle size is perhaps the dominant factor that determines the transportability of a class of sediment.

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TABLE 9. Summary of Radionuclide Presence at Instream Sampling Stations

	GVC			BC-1			EB			FC-1			BC-4			CC-1			CC-3			CC-5			CC-9			CC-11			Lake Erie		
	Dis.	Susp.	Bed	Dis.	Susp.	Bed	Dis.	Susp.	Bed	Dis.	Susp.	Bed	Dis.	Susp.	Bed	Dis.	Susp.	Bed	Dis.	Susp.	Bed	Dis.	Susp.	Bed	Dis.	Susp.	Bed	Dis.	Susp.	Bed	Dis.	Susp.	Bed
H-3	*	NA		*	NA	NA			NA	*	NA	NA	*	NA	NA																		
Be-7										*			*			*	*	*	*	*	*	*	*	*	*	*	*	*	*	*			*
K-40	*	*		*	*	*			*	*	*	*	*	*	*									*		*				*			
Mn-54					*								*																				
Co-57									*																								
Co-60									*			*	*		*	*		*		*	*			*									
Zn-65																				*	*												
Sr-90	*	*		NA	NA	NA			*	*	*	*	*	*	*	*	*		*	*	*	*	*	*	NA	NA	NA	*	*				*
Nb-95										*																							
Rh-101									*						*		*				*			*		*	*						
Rh-102									*	*		*			*				*											*			
Sb-125									*	*		*	*		*									*	*								
Cs-134		*				*			*		*	*			*					*	*	*			*								
Cs-137		*			*	*			*	*	*	*	*	*	*		*	*	*	*	*	*	*	*		*	*	*	*	*			*
Ce-141										*			*																				
Ce-144		*															*							*				*					*
Eu-152																					*			*									
Eu-155		*				*							*			*		*		*	*		*	*					*	*			*
Pb-210					*											*												*		*			
Bi-207									*			*									*									*			
Ra-226		*			*	*			*		*	*		*	*		*	*		*	*	*	*	*	*	*	*	*	*	*			*
Ra-228	*																					*											
Th-228		*		*	*	*			*		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*			*
Th-232		*			*	*			*	*	*	*	*	*	*	*	*	*		*	*		*	*		*	*		*	*			*
U-235					*	*			*		*	*		*	*		*	*		*	*		*	*	*	*	*		*	*			*
U-238		*			*	*			*			*	*	*	*	*		*	*	*	*	*	*	*		*	*	*	*	*			*
Pu-238				NA	NA	NA			*	*	*	*	*	*	*	*	*	*		*	*		*	*	NA	NA	NA		*				*
Pu-239, 240		*		NA	NA	NA			*	*	*	*	*	*	*	*	*	*	*	*	*		*	*	NA	NA	NA	*	*				*
Am-241	*	*		*	NA	NA			*	*	*	*	*	*	*	*	*	*	*			*	*	*	*	NA	NA	*	*	*			*
Cm-244	*	*		NA	NA	NA			*	*	*	*	*	*	*		*	*	*		*		*	*	NA	NA	NA						*

---

* indicates radionuclide was found at one or more sampling points per station.
NA = Not analyzed
Dis. = Dissolved Radionuclides
Susp. = Radionuclides associated with suspended sediment
Bed = Radionuclides associated with bed sediment

The sizes range from boulders down to the finest of clay particles. Two distinct catatories of stream sediment load can be defined for the range of sizes: 1) bed material load, 2) wash load.

The bed material load consists of sand sizes and larger particles that have sufficiently high settling velocities and tend to concentrate near the streambed during transport. These particles become part of the streambed during low flow conditions. The wash load consists of silt and clay sized material that tend to be dispersed rather uniformly through the water column. The finer particles of this category can be colloidal in behavior when considering settling velocities.

This distinction has been introduced for two reasons. First, there is a great difference between the transport velocity of the two categories. The wash load moves through the river system with the same velocity as the water. During floods, the washload particles can easily travel from their point of origin in the watershed to their point of final deposition. In constrast, the bed material transport velocity is several orders of magnitude less than the flow. During floods, the bed material load travels only short distances and traverses these distances in short hops. Bed particles can require years to travel the same distance wash load particles travel during one flood event.

The second reason for the distinction between the two categories is that the wash load is source dependent. It is derived primarily from overland flow during rainfall-runoff events and is determined by erosion characteristics of the watershed. The bed material is already available in the stream channel bed and moves only when sufficient water velocity is reached. Therefore, the rate of transport of bed particles depends on the availability of particles in the bed and the flow rate of the stream.

Phase 2 Conditions

During the Phase 2 sampling program, the water velocities and discharges were low enough to where very small perentages of sand fractions were in transport. As shown in Table 7, the bulk of the suspended sediment was washload (clay and silt) at the sampled points. Because of the very small percentages of sand (bed material load) in the suspended sediment the sand fractions were not included in the laboratory analysis of radionuclide activity levels. The following discussion of results considers the radionuclides associated with bed sediment and suspended sediment, and the dissolved radionuclides separately.

Bed Sediment

Springville Dam and Reservoir act as a sediment trap for the incoming bed material load. A significant portion of the washload is also trapped as illustrated by the percentages of sand, silt, and clay present in the bed sediment at the CC-5 samping stations (Table 8). Most of the coarser fractions such as sand and gravel settle out upstream of the CC-5 station. Practically all incoming sediment is trapped in Springville Reservoir for time periods of about a year or more until the gates of Springville Dam are opened and large volumes of sediment are flushed through to the downstream reaches.

Potassium-40 (Figure 5)

The higher levels of Potassium-40 were associated with clay. The maximum value for clay was 59.3 ± 34.9 pCi/g detected at the Buttermilk Creek background station BC-1. The activity levels for sand and silt were practically the same with the levels for silt slightly higher. Potassium-40 appears to be almost uniformly distributed per sediment class for the sampling stations including both background stations BC-1 and CC-1. No downstream trend is apparent.

Cesium-134 (Figure 6)

The highest activity levels are associated with clay with no definite trend indicated between sand and silt as to which has the lowest activity. Cesium-134 was found predomonantly at the stations in close proximity to the NFS facilities. The highest activity levels for sand and silt were found in Erdmans Brook with a gradual decrease in the downstream direction to BC-4 near the mouth of Buttermilk Creek. The background station BC-1 near the facilities showed relatively very low levels as did the background station at CC-1 on Cattaraugus Creek. Both BC-1 and CC-1 are not affected by water and sediment outflow from Franks Creek. Downstream at the Springville Reservoir stations (CC-5/1, 5/2, and 5/3) Cesium-134 was sparsely found at the three sampling

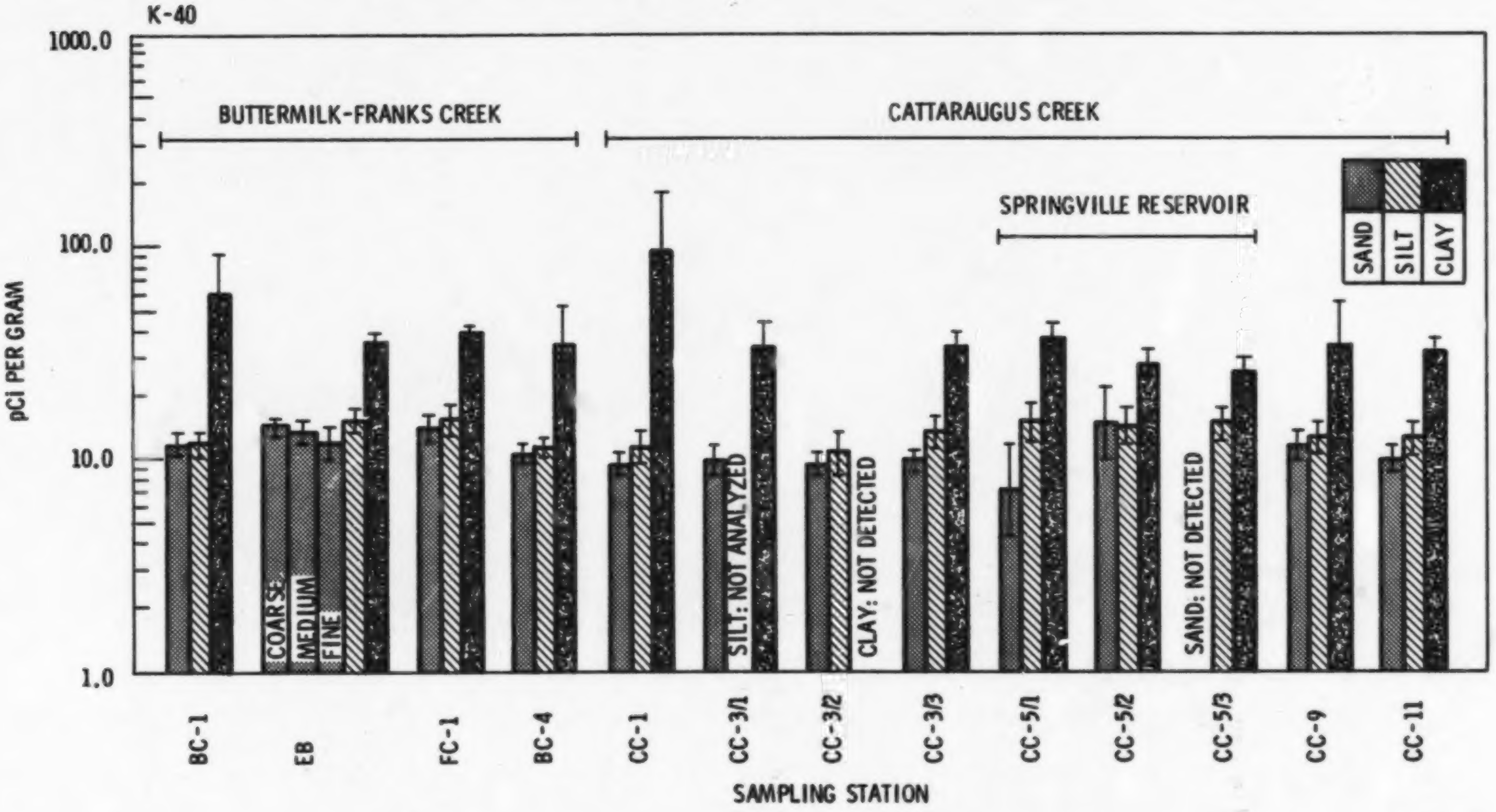

FIGURE 5. Potassium-40 Associated with Bed Sediment

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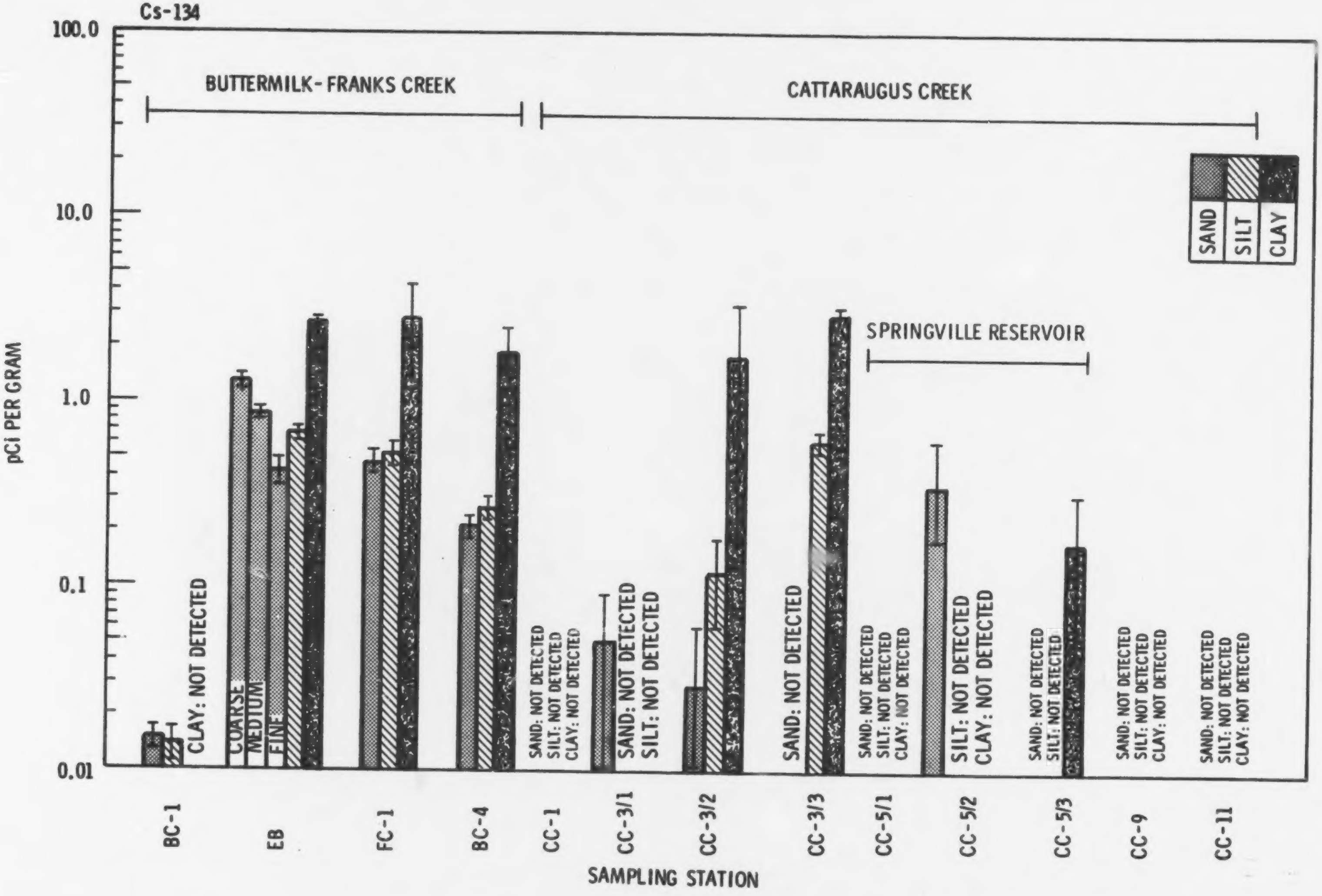

FIGURE 6. Cesium-135 Associated with Bed Sediment

stations and was below detection downstream of the dam. Considering the fact that Cesium-134 was detected in all three sediment classes at Stations EB, FC-1, and BC-4 at significantly higher levels as compared to the nearby background stations and a trend of decreasing activity downstream, the NFS site appears to be a source of Cesium-134. That the radionuclide was not found in appreciable levels in Springville Reservoir and was not detected downstream except at one sampling point in Lake Erie may be attributed to its short half-life of about two years.

Cesium-137 (Figure 7)

The results for Cesium-137 indicate that the NFS facilities are a source of this radionuclide. Activity levels at BC-1 (background) were either very low or below detection. The station at or near the NFS site had the highest overall activity levels for sand, silt and clay. Although station FC-1 and CC-3/3 both recorded levels of 134.0 ± 9.89 pCi/g for clay which were the highest for any sediment, the general trend is a decrease in levels in the downstream direction. The trend for sand is one of high activity levels at Station EB near the NFS site (72.1 ± 0.5 pCi/g), which was detected on the coarse fractions, to near uniform levels from 2.04 ± 0.16 to 1.14 ± 0.07 pCi/g at CC-3 and CC-5. Below Springville Dam the activity levels drop to less than that of the reservoir levels to 0.34 ± 0.06 pCi/g at CC-9 and 0.73 ±0.05 pCi/g at CC-11.

Radium-226 (Figure 8)

The highest activity levels were detected in clay with the maximum value of 4.96 ± 3.37 measured at Station CC-3/2. The downstream trend in activity levels for clay seems to be one of increasing values considering the relatively higher levels found at CC-3/2 and CC-9. Silt has the next highest levels but indicates no trend among the stations. Sand has the least activity but does show gradual decrease in activity levels downstream from the NFS site. At Springville Reservoir, no levels of activity were recorded for sand at two out of three stations (CC-5/1 and 5/2). However, the highest level for sand at any station was measured for CC-5/3 (2.23 ± 1.13 pCi/g). The background stations all had similar levels as most other stations.

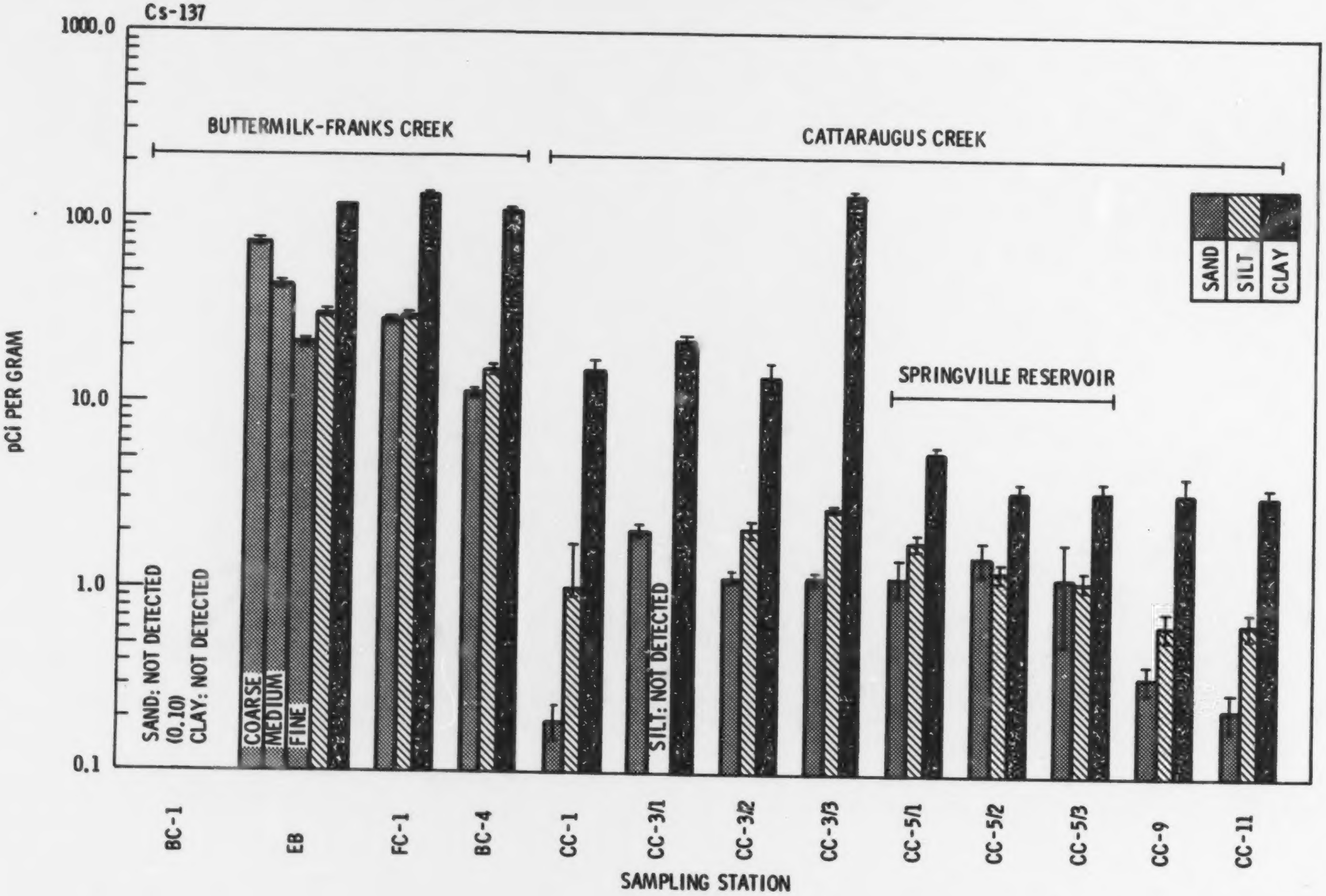

FIGURE 7. Cesium-137 Associated with Bed Sediment

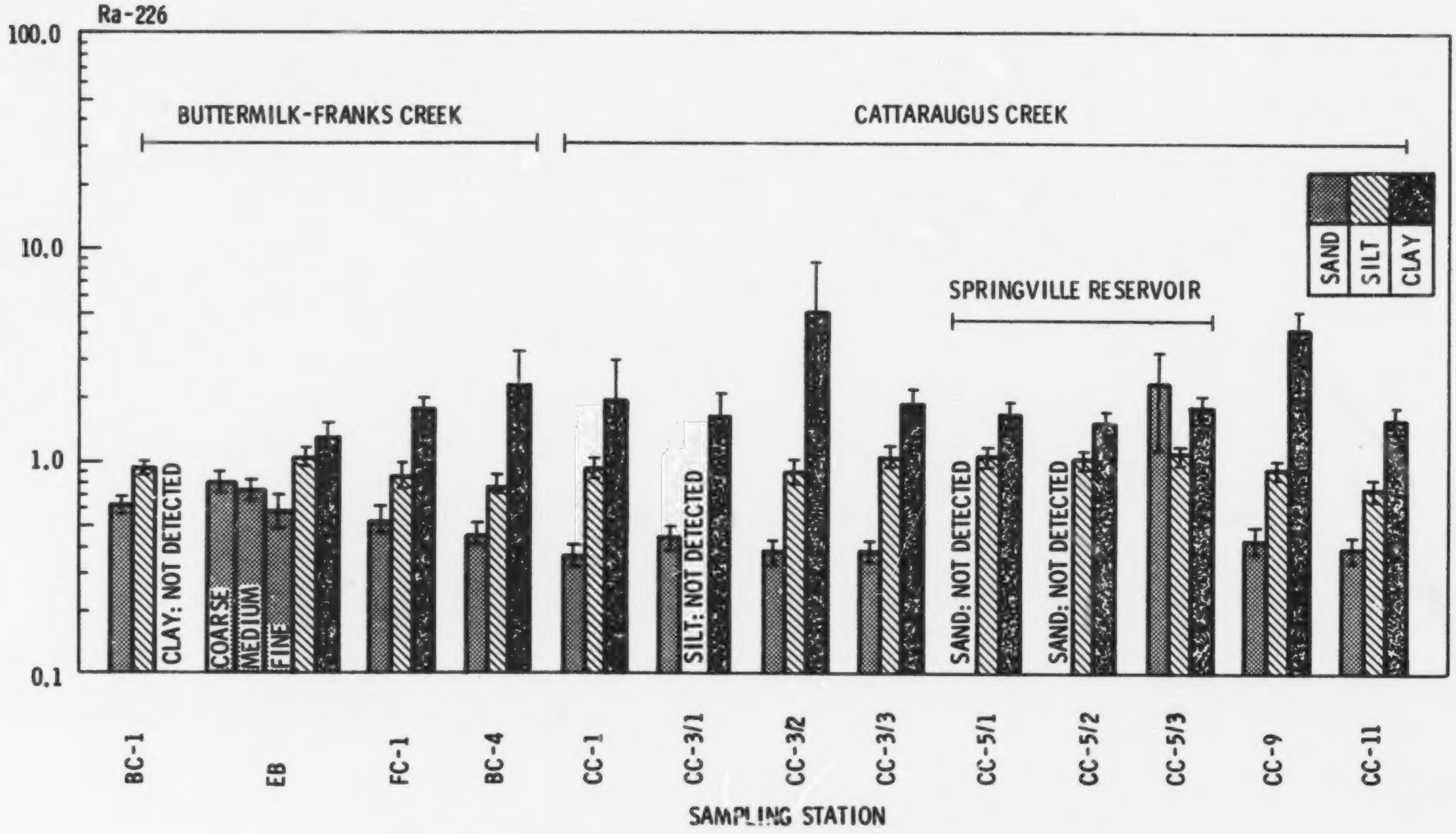

FIGURE 8. Radium-226 Associated with Bed Sediment

Thorium-228 (Figure 9)

The highest activity levels are associated with clay where a maximum value of 5.33 ± 3.02 pCi/g was measured at CC-3/2. No definite trend is apparent for either clay or silt. Sand shows the only trend with relatively higher levels at the upstream stations BC-1, EB, and FC-1 in the vicinity of the NFS site. However, BC-1 is considered a background station for Buttermilk Creek and shows about the same levels as the stations on the facilities drainage system. There is a gradual decrease in activity level downstream from the Erdmans Brook Station (EB) until station CC-5 at Springville Reservoir is reached. The stations at CC-5/2 and CC-5/3 the only other locations besides station EB where the activity exceeds that of the background station BC-1. The maximum activity for Thorium-228 associated with sand was detected at CC-5/3 (1.87 ± 1.1 pCi/g). This trend may indicate a tendency for higher levels of Thorium-228 to accumulate in Springville Reservoir.

Thorium-232 (Figure 10)

The activity levels for sand indicate a similar trend as that for Thorium-228. The highest activity level for sand (3.57 ± 1.85 pCi/g) was measured at Springville Reservoir at Station CC-5/3. The clay samples yielded the highest overall levels with a maximum of 6.17 ± 2.54 pCi/g at BC-4.

Uranium-235 (Figure 11)

The highest activity levels are associated with clay with the maximum level of 2.02 ± 1.05 pCi/g found at BC-1. The lowest levels are typically associated with sand except for two of the Springville Reservoir stations where levels are higher than either silt or clay. The maximum value for sand was 1.08 ± 0.81 pCi/g measured at CC-5/3. The downstream trend for sand is similar to that for Thorium-228 and 232. The levels decrease downstream from the sampling stations in the vicinity of the NFS site, including the background Station BC-1, until Springville Reservoir. The levels increase sharply and drop again downstream of the dam. There is no definitive trend for clay and silt.

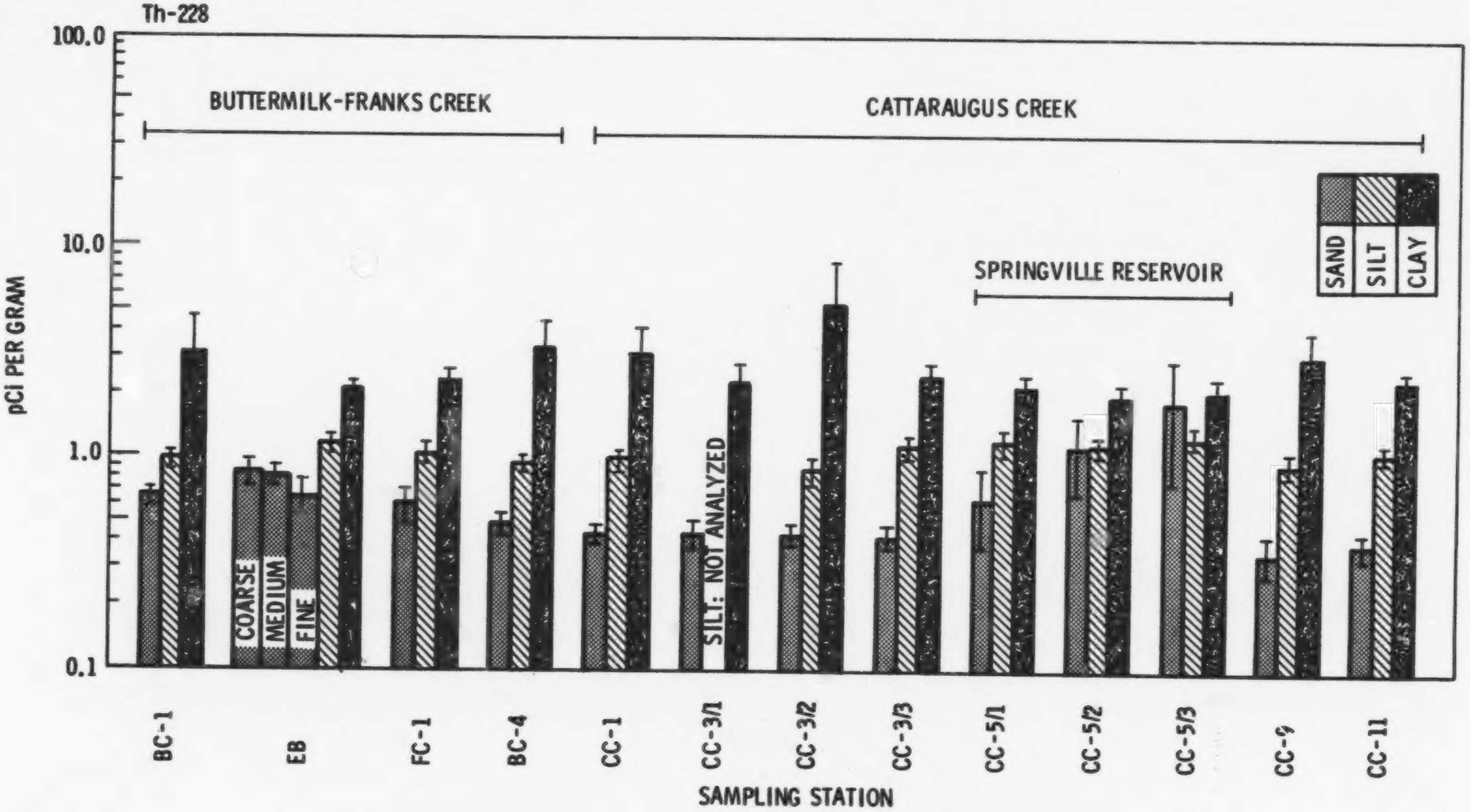

FIGURE 9. Thorium-228 Associated with Bed Sediment

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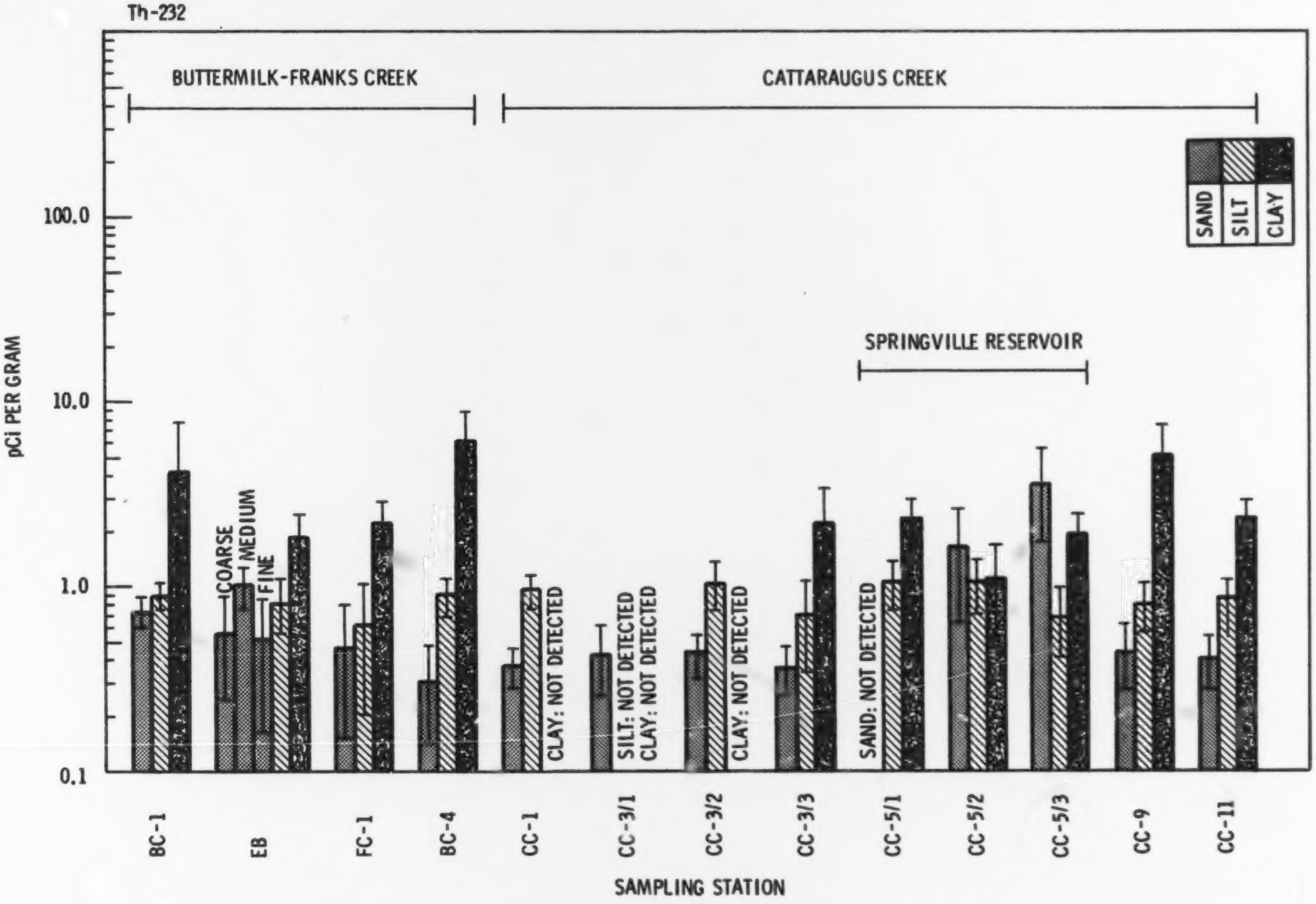

FIGURE 10. Thorium-232 Associated with Bed Material

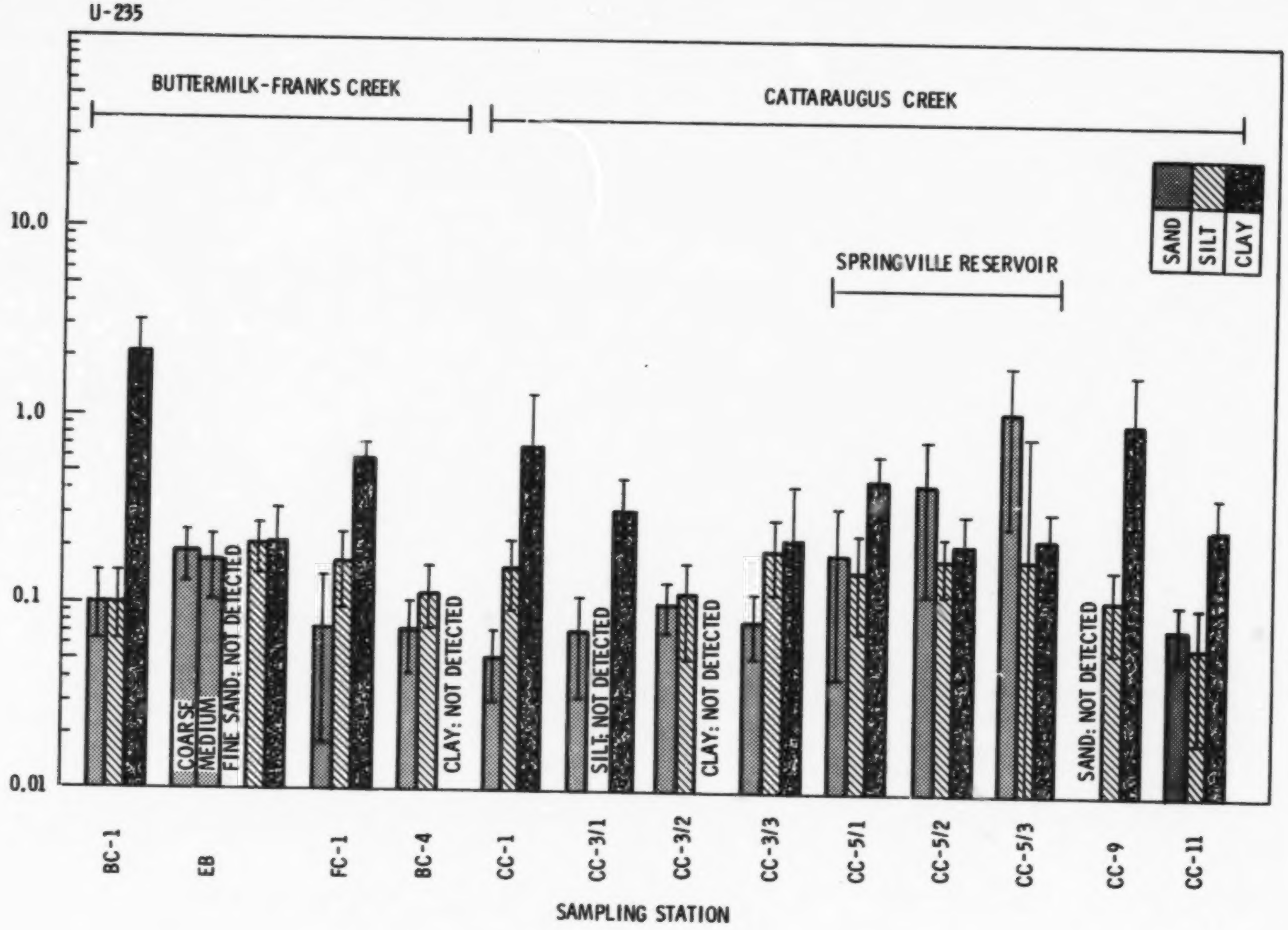

FIGURE 11. Uranium-235 Associated with Bed Sediment

Uranium-238 (Figure 12)

Uranium-238 was detected for sand, silt and clay at the two stations along the NFS facilities drainage system (EB and FC-1). The higher activity levels are associated with clay with the maximum of 3.57 ± 1.52 pCi/g measured at FC-1. At the background stations BC-1 and CC-1 and at most of the downstream sampling points, activity levels for clay were below detection. A similar trend exists for silt. The activity levels for sand decreased in the downstream direction from the NFS site to below detection level at Springville Reservoir and only found at one other station below the dam (CC-9).

Strontium-90 (Figure 13)

The trend for Strontium-90 is one of decreasing activity levels downstream from the Erdman's Brook station (EB). The highest activity levels for sand (1.57 ±0.17 pCi/g), silt (3.42 ± 0.21 pCi/g), and clay (11.07 ± 0.65) were found at station EB. The levels at the background station CC-1 were all below detection. The much higher levels at station EB relative to other stations, the below detection levels at the background station CC-1, and the decreasing activity downstream, all indicate the NFS site as a source of Strontium-90.

Plutonium-238 (Figure 14)

Plutonium-238 was detected at all stations. The highest values are associated with clay where the maximum activity level of 0.057 ± 0.006 pCi/g was detected at EB. The activity levels for the Buttermilk-Franks Creek system were significantly higher than the Cattaraugus Creek stations. The decreasing trend in the downstream direction indicates that the NFS site is a possible source of Plutonium-238.

Plutonium-239,240 (Figure 15)

The trends for Plutonium-239,240 are very similar to those for Plutonium-238. It was detected at all stations and the highest values are associated with clay at Station FC-1 (0.045 ± 0.006). The highest activity levels are found for stations of the Buttermilk-Franks Creek system therefore the NFS site is a possible source of Plutonium-239,240.

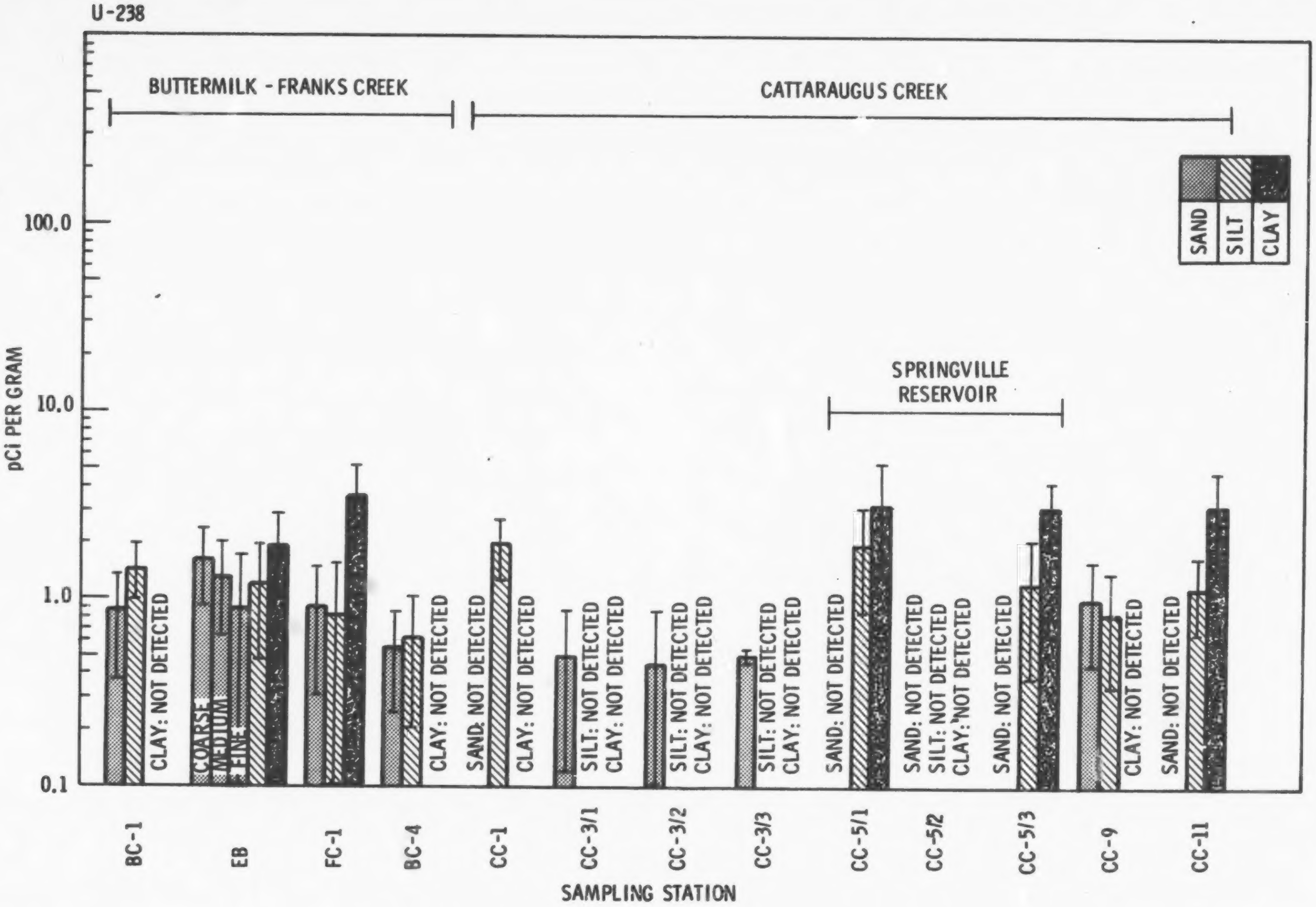

FIGURE 12. Uranium-238 Associated with Bed Sediment

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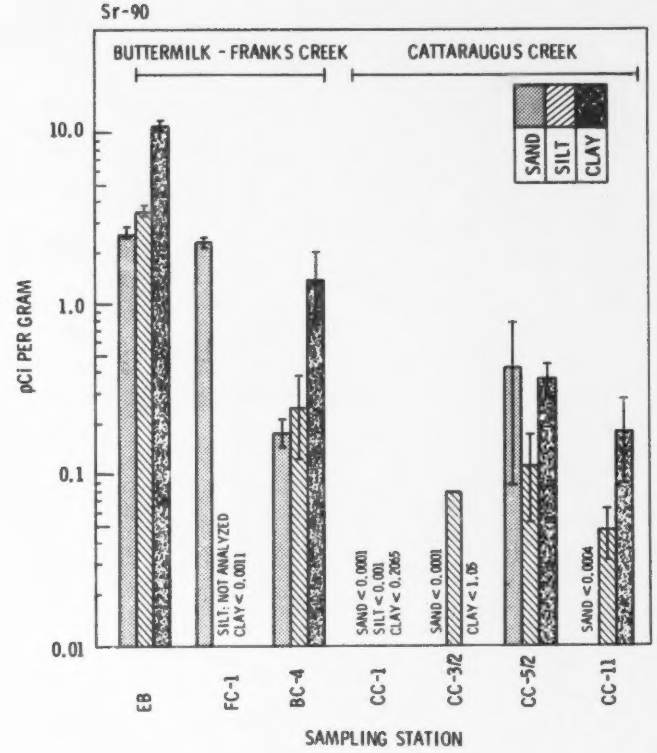

FIGURE 13. Strontium-90 Associated with Bed Sediment

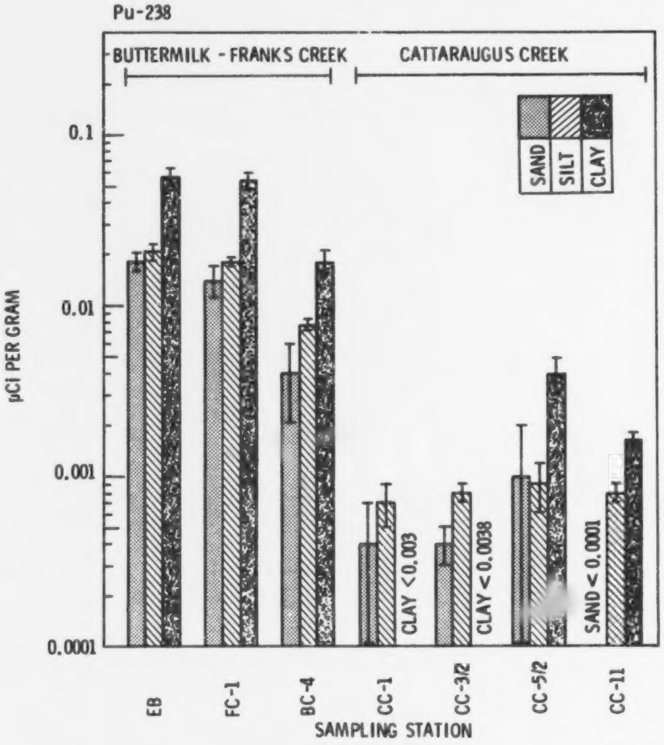

FIGURE 14. Plutonium-238 Associated with Bed Sediment

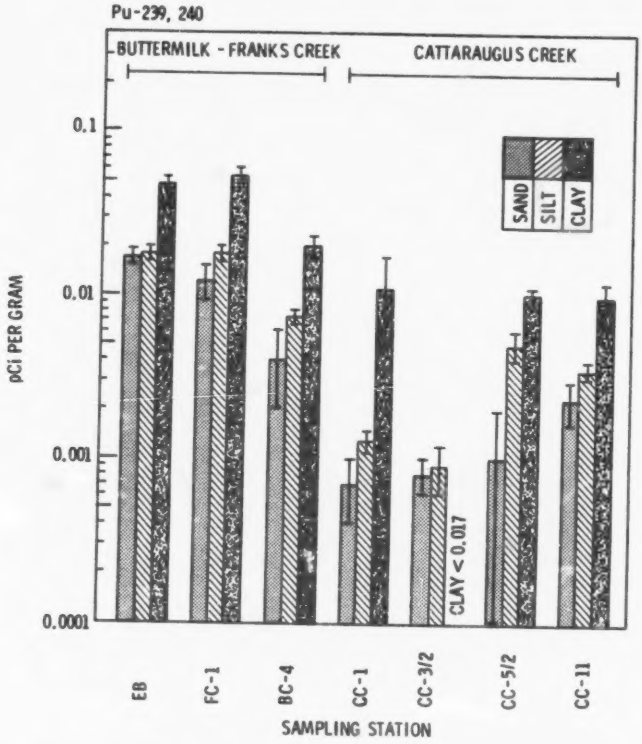

FIGURE 15. Plutonium-239,240 Associated with Bed Sediment

Americium-241 (Figure 16)

Americium-241 was found primarily in the samples from the Erdman's Brook-Franks Creek system that drains the NFS facilities. It was found in sand, silt and clay for both stations EB and FC-1. The maximum level of 0.072 ± 0.009 pCi/g was measured at Station EB and was associated with clay. Americium-241 was mostly below detection at stations downstream of Franks Creek. The background station at CC-1 has a comparably high activity level for clay (0.065 ± 0.026 pCi/g). Based on the fact that Americium-241 is present in all three sediment classes with the relatively higher levels, the NFS facilites may be a source of this radionuclide.

Curium-244 (Figure 17)

Curium-244 was not detected in sand and shows no trend with respect to the NFS site. The highest activity levels were found to be associated with clay with the maximum value of 0.046 ± 0.021 pCi/g at CC-3/2.

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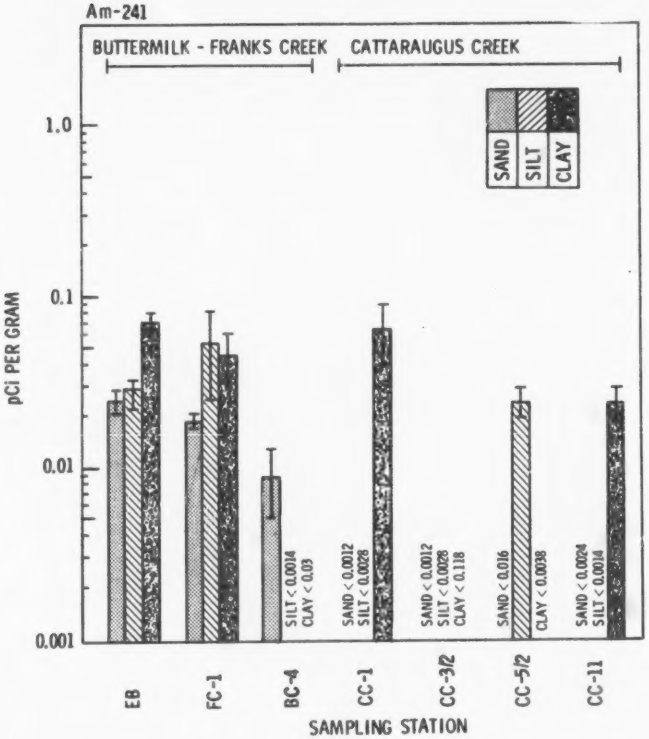

FIGURE 16. Americium-241 Associated with Bed Sediment

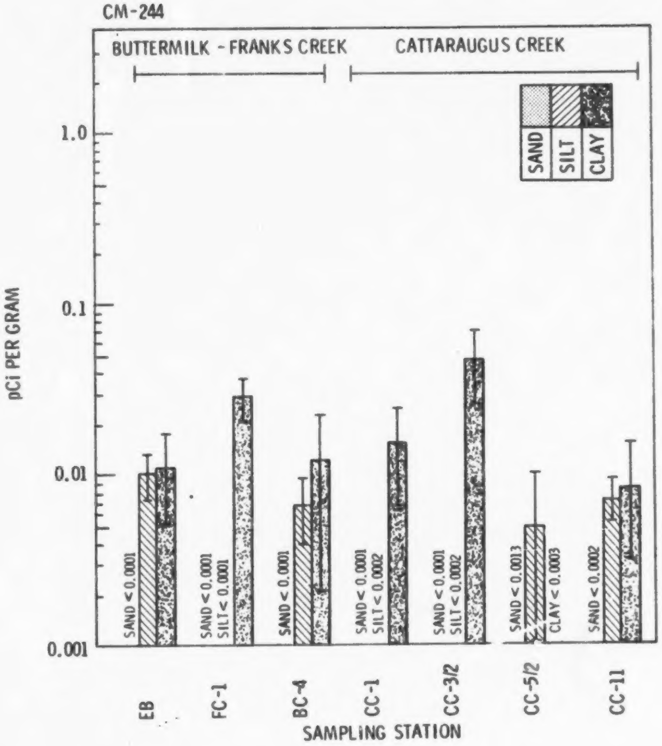

FIGURE 17. Curium-244 Associated with Bed Sediment

Lake Erie Bed Sediment

The Lake Erie samples were taken less than a mile outshore from the mouth of Cattaraugus Creek in an area where flood deposits of sediment from the creek would likely accumulate. The core samples were separated into two-inch sections for analysis. Gamma counting was performed on all three two-inch sections at each station (Table D.2). Only the top two-inch sections were analyzed radiochemically because of the cost per sample (Table D.4). All samples were analyzed as composites without separation into sand, silt, and clay.

The same gamma-emitting radionuclides that were prevalent in the Cattaraugus-Buttermilk Creek samples were found in Lake Erie sediment. These are Potassium-40, Cesium-137, Radium-226, Thorium-228 and 232, and Uranium-235 and 238. There was no trend indicated as to which section of the core samples had higher activity levels. However, sampling point four consistenty had lower overall activity levels than the other three sampling points.

The results of samples analyzed radiochemically indicated that Strontium-90, Plutonium-238, and 239,240, Americium-241, and Curium-244 were all detected in the Lake Erie sediment. Sampling points 1 and 2 had the most consistent detectable levels of the five radionuclides. Plutonium-239,240 was detected at all four sampling points.

Suspended Sediment

Only the clay and silt samples (wash load) were analyzed since all the sand samples were less than one gram. Cesium-137 indicated significant levels of activity above background of the seven radionuclides plotted in Figures 18 through 24. These higher levels were found only at Station FC-1 in the surface drainage water from the NFS facilities. The activity level for clay and silt were 32.5 ± 1.5 pCi/g and 11.7 ± 0.6 pCi/g, respectively. These levels are considerably lower than those for bed sediment at this station. The corresponding activity levels for bed clay and silt at station FC-1 were 134.0 ± 0.90 pCi/g and 28.6 ± 0.60 pCi/g, respectively. Although FC-1 is the only station analyzed for the NFS facilities drainage system, it does show considerably higher levels as compared to the other stations and corresponds to the trend of the bed sediment. This would reinforce the possibility of the NFS site as a source of cesium-137.

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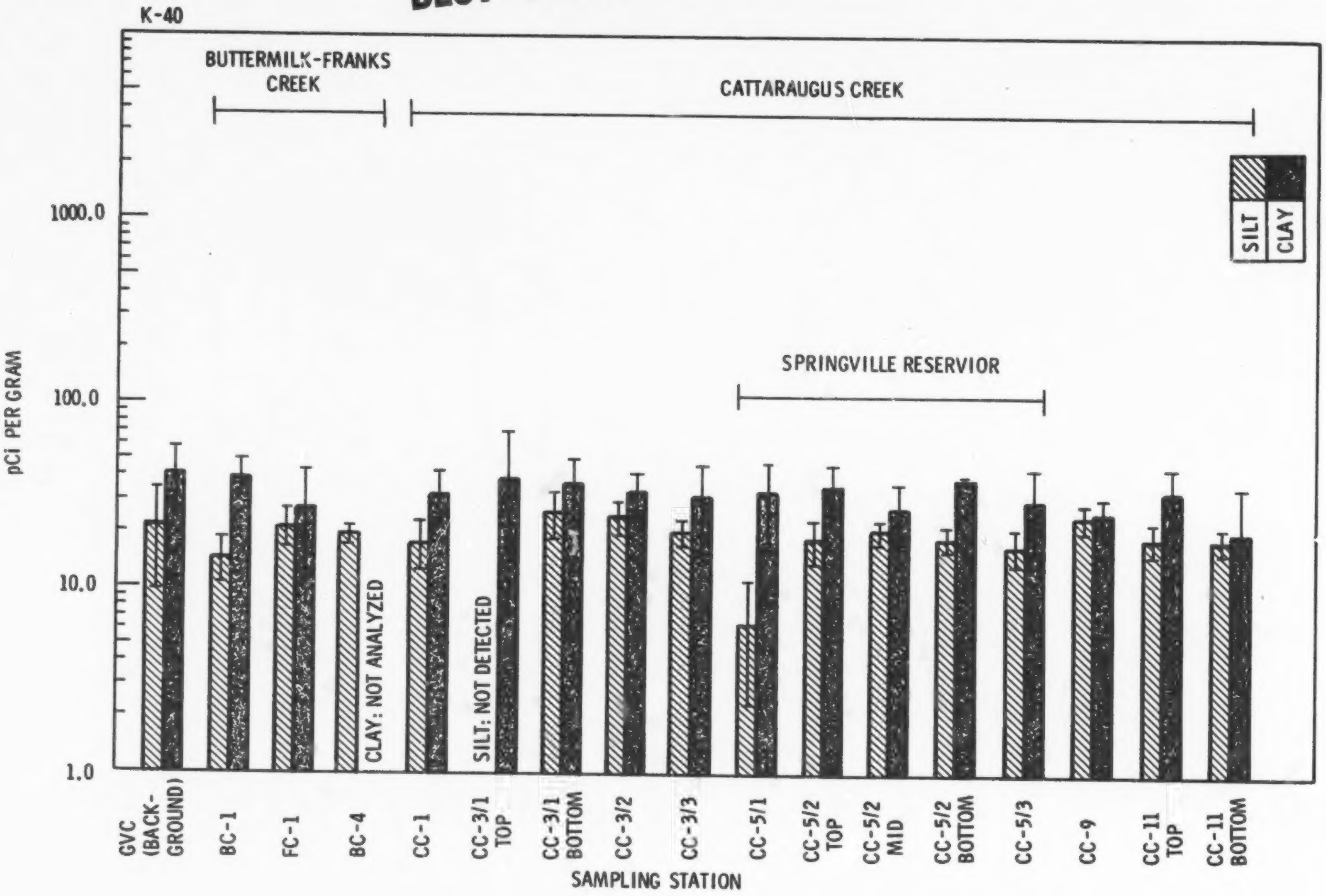

FIGURE 18. Potassium-40 Associated with Suspended Sediment

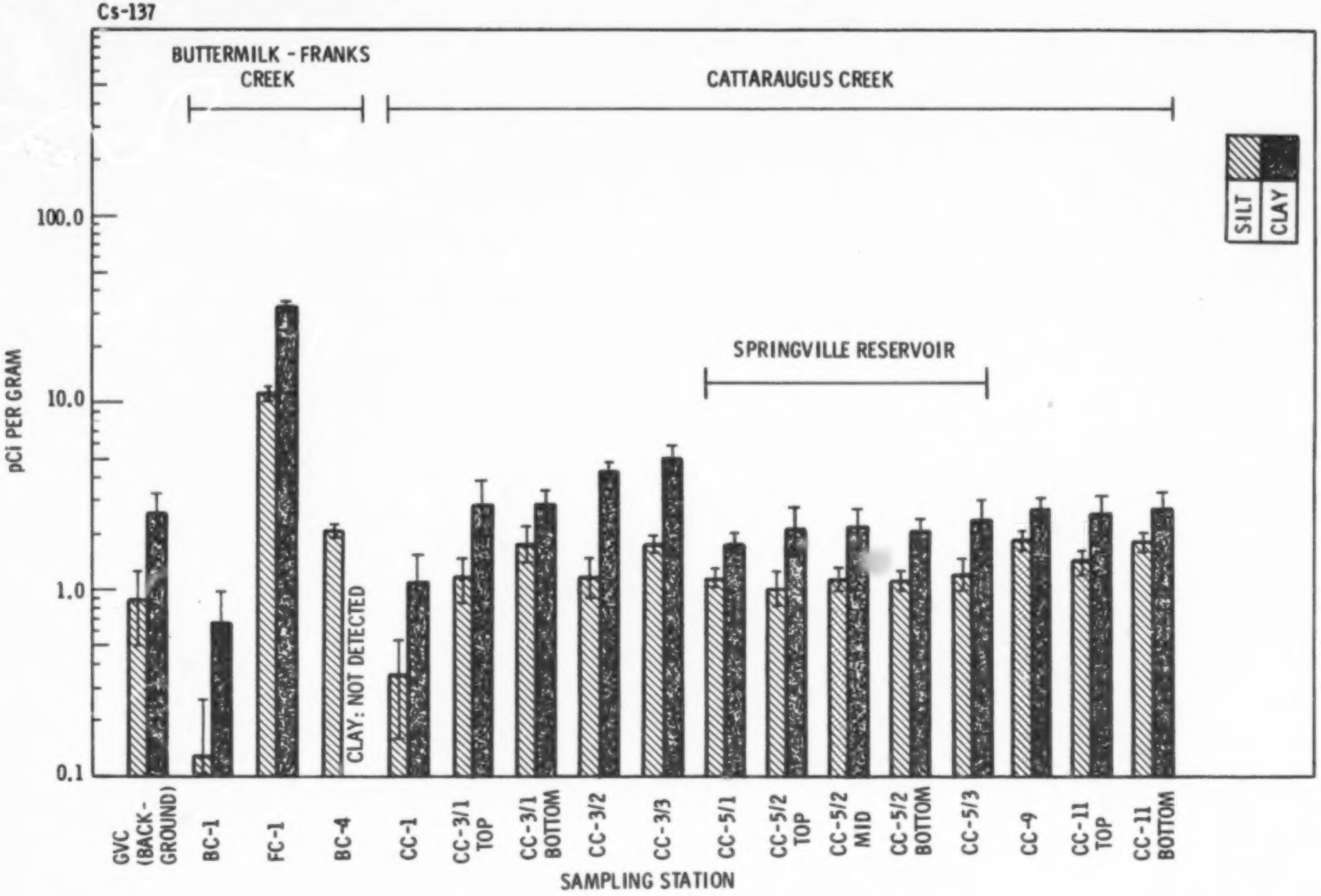

FIGURE 19. Cesium-137 Associated with Suspended Sediment

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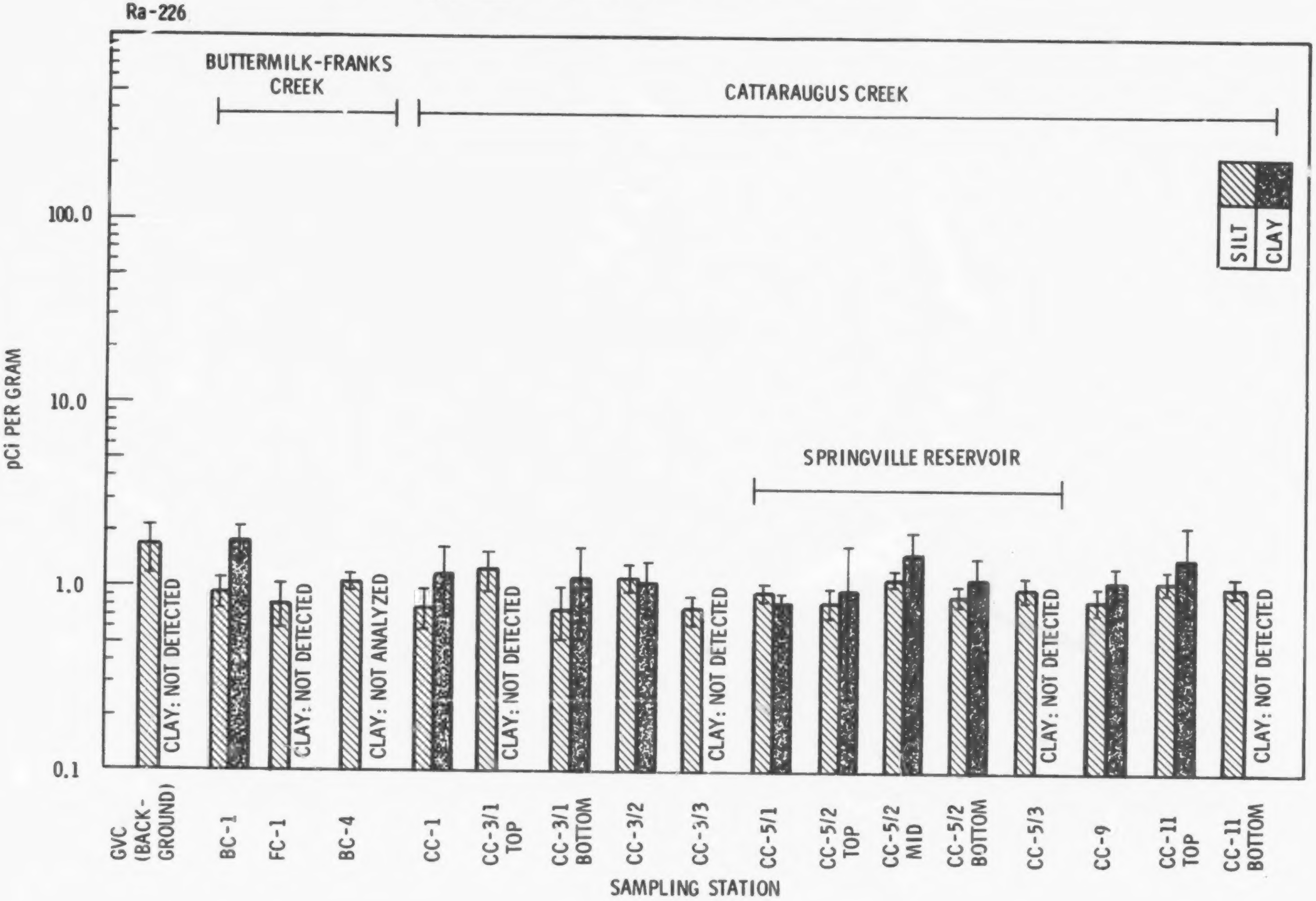

FIGURE 20. Radium-226 Associated with Suspended Sediment

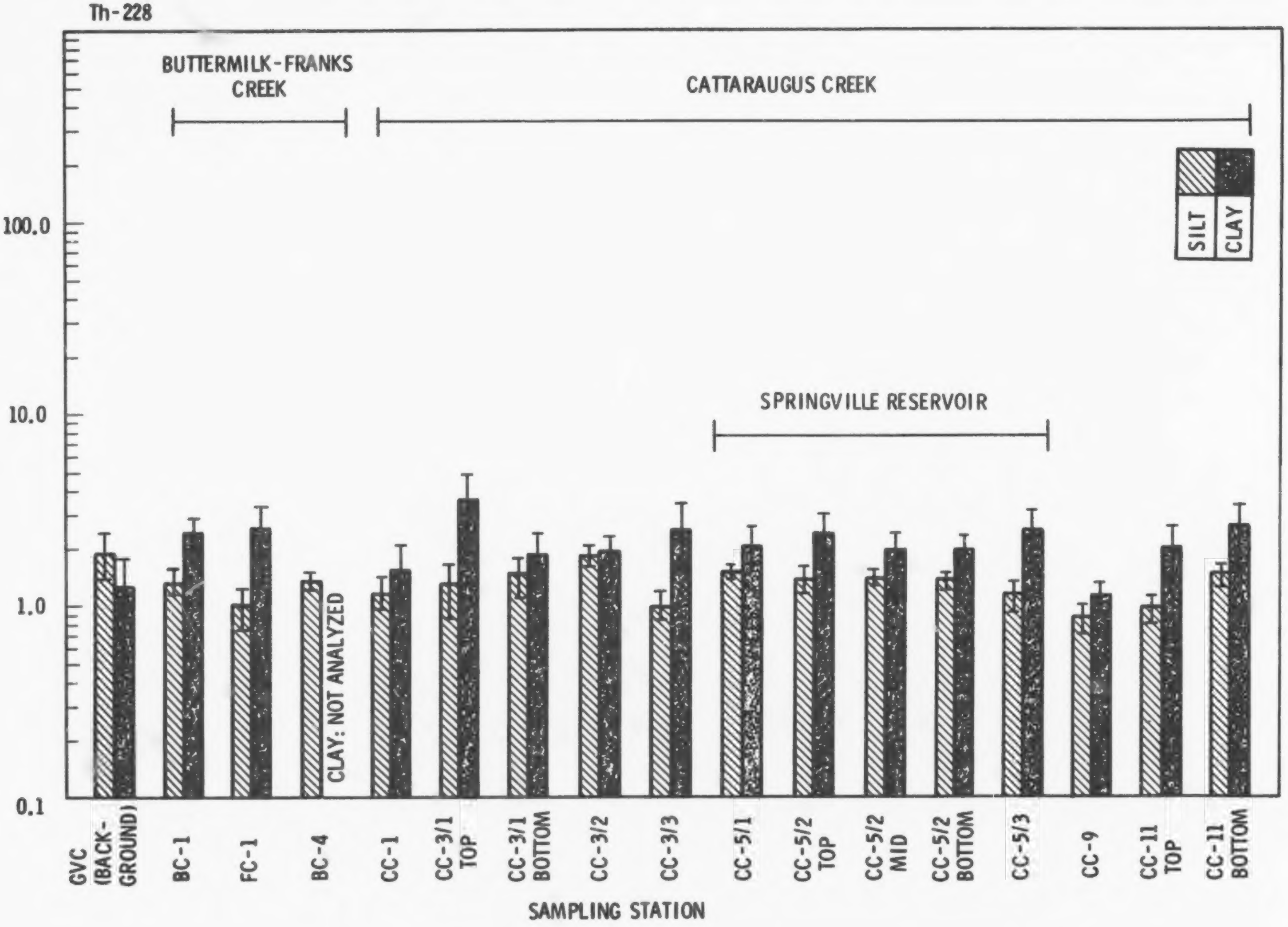

FIGURE 21. Thorium-228 Associated with Suspended Sediment

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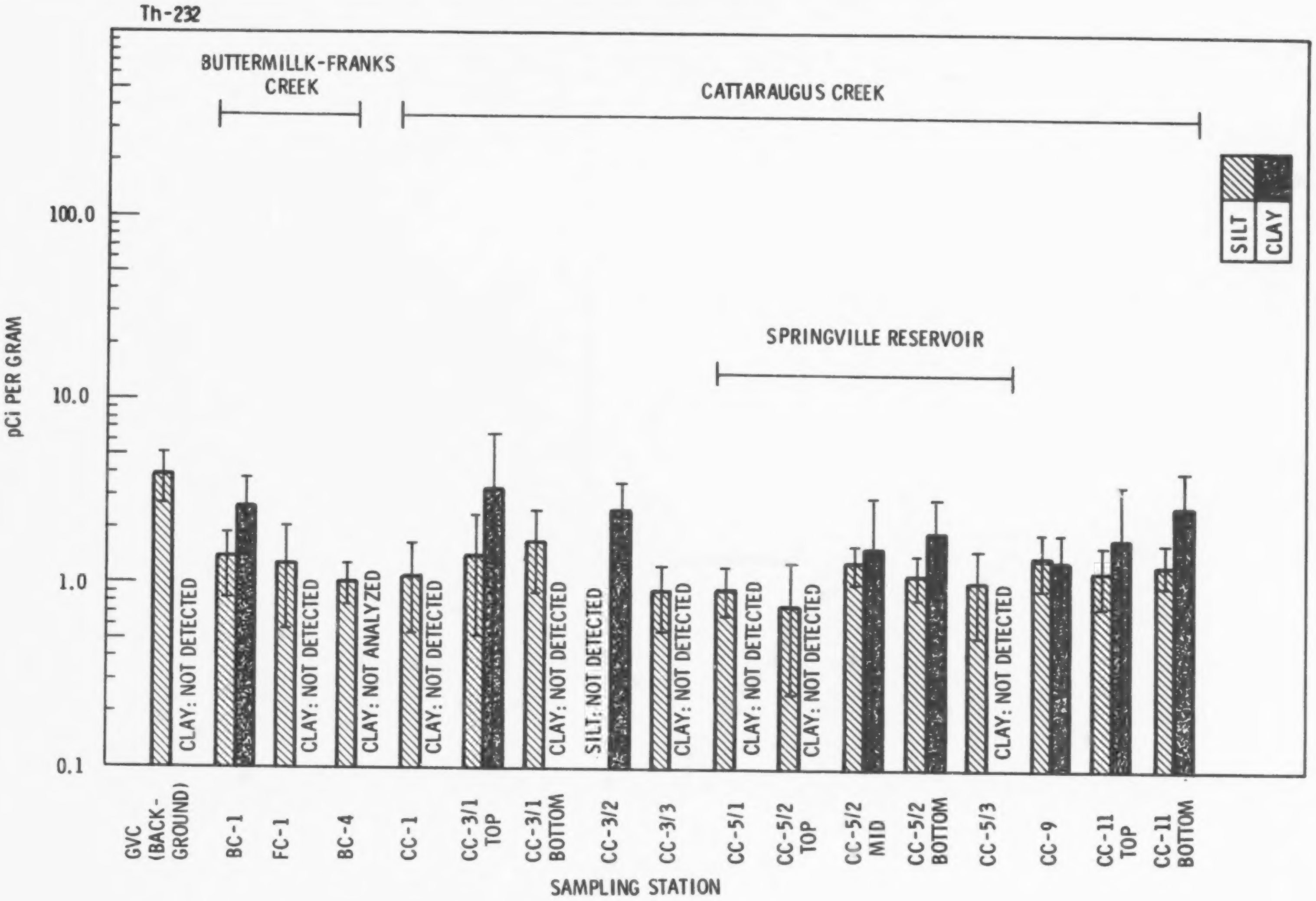

FIGURE 22. Thorium-232 Associated with Suspended Sediment

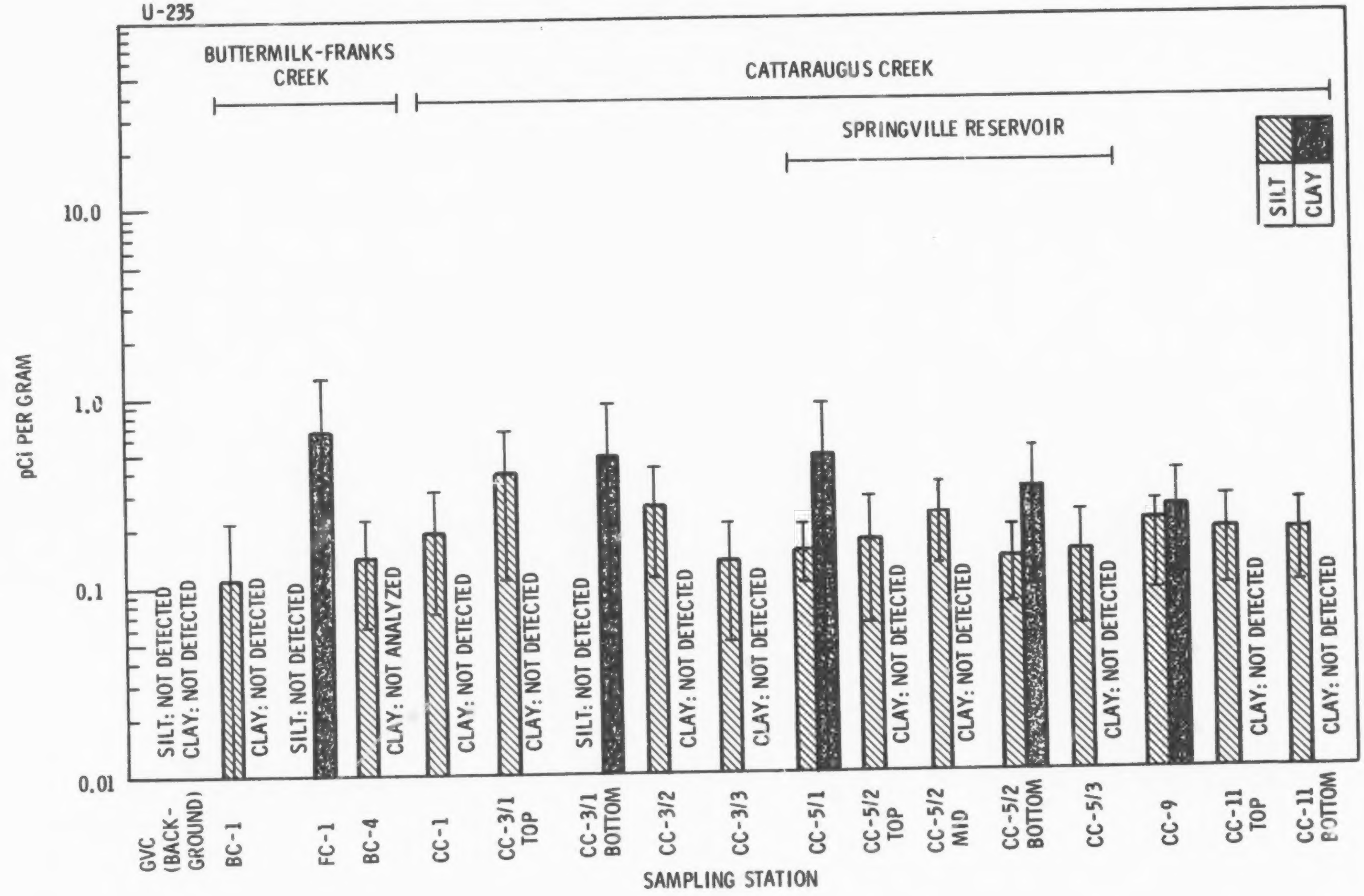

FIGURE 23. Uranium-235 Associated with Suspended Sediment

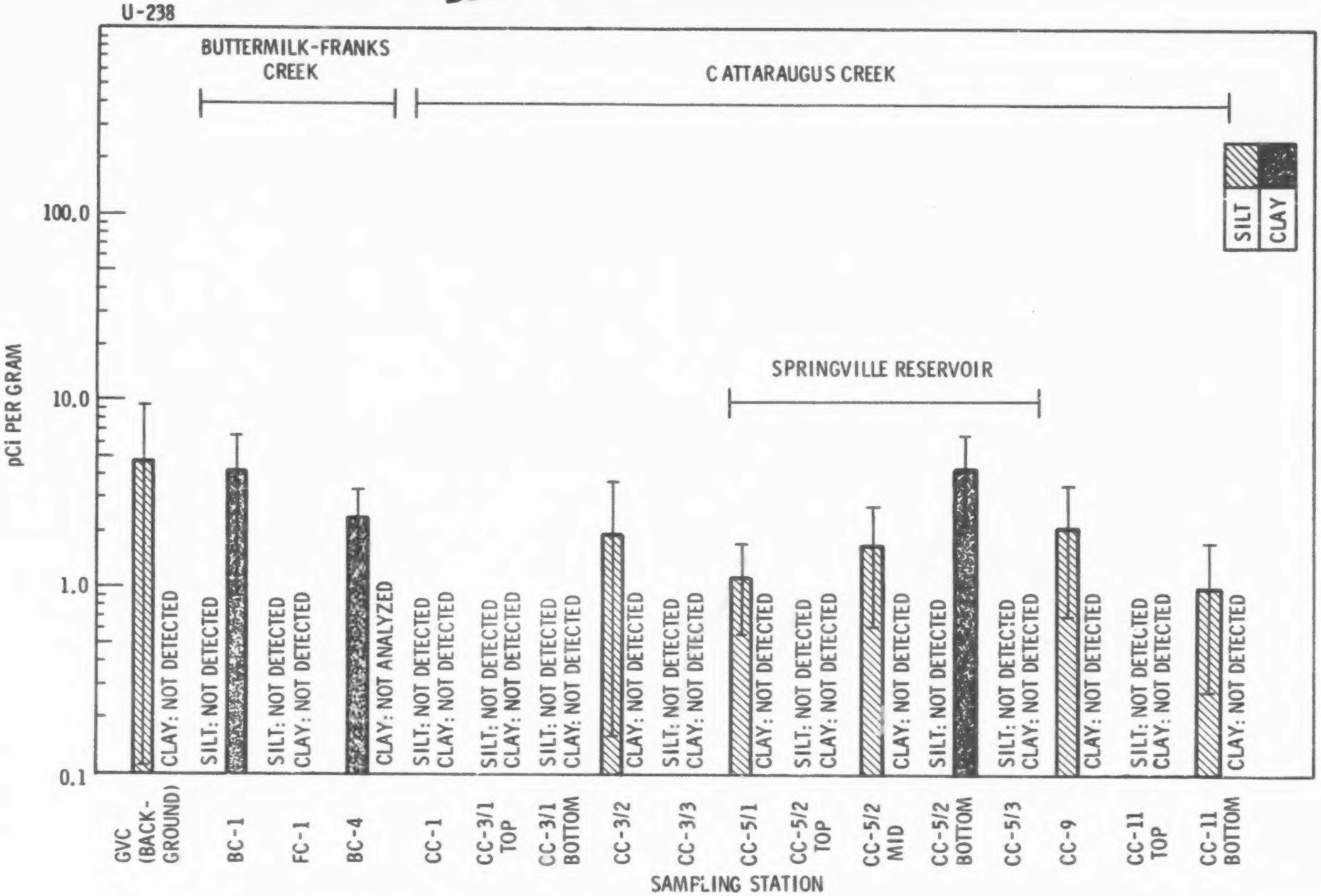

FIGURE 24. Uranium-238 Associated with Suspended Sediment

The radionuclides Potassium-40, Cesium-137, Radium-226, and Thorium-228 were all consistently detected in both bed and suspended sediment. Thorium-232, and Uranium-235 and 238 were detected much less frequently in the suspended sediment as compared to the bed sediment samples.

Clay had consistently higher activity levels than silt for potassium-40, Cesium-137, Radium-226, Thorium-228 and 232, and Uranium-235. There was not enough Uranium-238 detected at the sampling stations to indicate a trend.

Radiochemical analyses were performed to determine the activity levels of Strontium-90, Plutonium-238 and 239, 240, Americium-241, and Curium-244 as shown in Figures 25 through 29, respectively. The background levels of clay and silt at GVC and CC-1 were about the same order of magnitude as the levels at the other stations for the five radionuclides. Detectable levels were recorded at GVC and CC-1 for either silt or clay or both except for plutonium-238. The higher activity levels for strontium-90, plutonium-239, 240, americium-241, and curium-244 were consistently found at the sampling stations in the upper reaches of the drainage basin such as GVC, CC-1, FC-1, and BC-4.

The overall levels for isotopes analyzed radiochemically were higher in the suspended sediment samples as compared to the bed sediment samples. The opposite trend occurred for the gamma-emitting radionuclides.

Dissolved Radionuclides

Detectable levels of radionuclides were found less frequently in the waters of the Cattaraugus-Buttermilk Creek system than in the sediment. However, of the radionuclides found consistently in dissolved form, all were also found consistently in the sediment. The dominant radionuclides found by gamma-counting were Potassium-40, Cesium-137, Thorium-228, Uranium-238, and Americium-241. The results are plotted in Figures 30 through 34, respectively. The radiochemical analysis found activity levels of Strontium-90, Plutonium-238, Plutonium-239, 240, Americium-241, and Curium-244 as shown in Figures 35 through 39, respectively.

Only Cesium-137 indicated a significantly higher activity level at the Franks Creek sampling station for gamma counting analysis. The activity levels decrease in the downstream direction and Cesium-137 was not detected at all

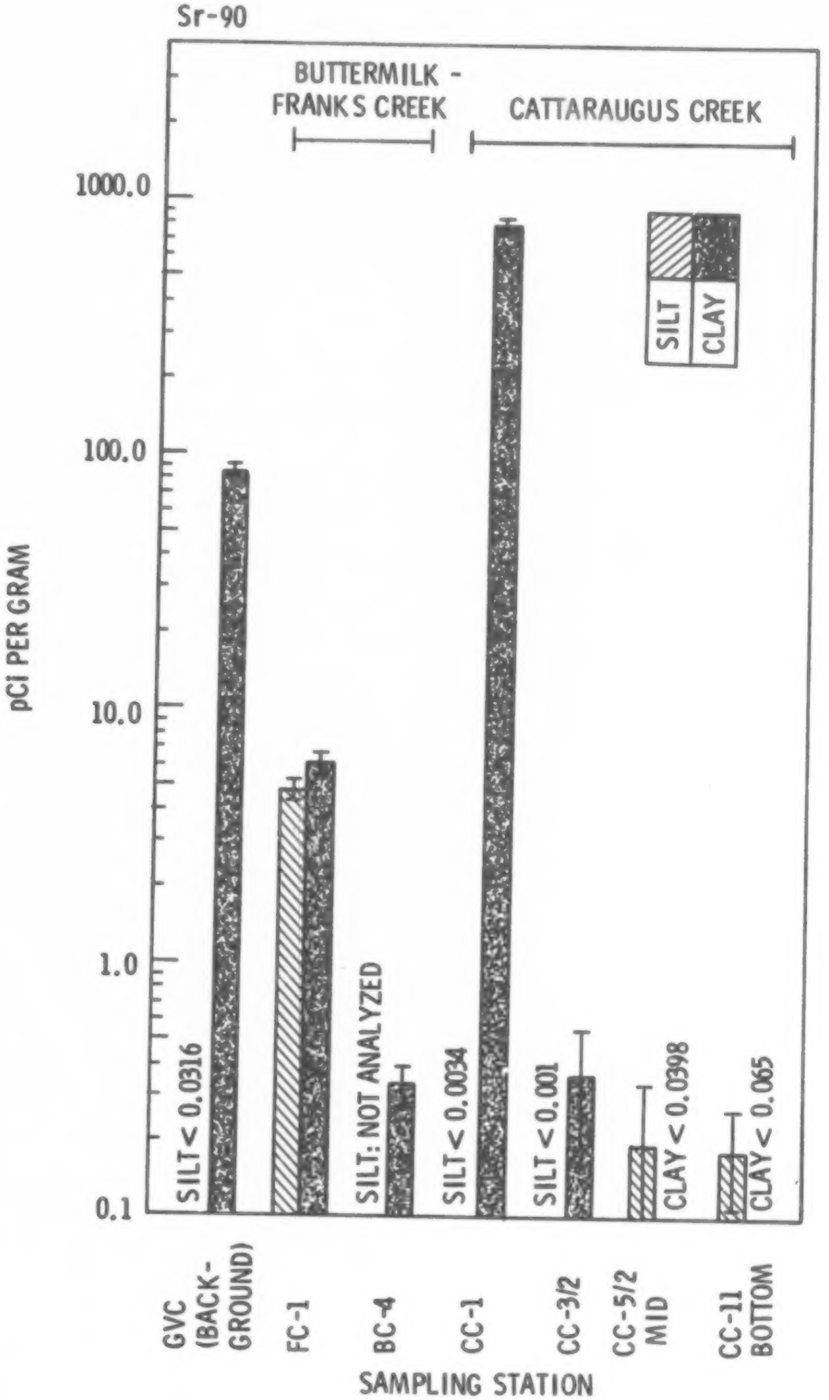

FIGURE 25. Strontium-90 Associated with Suspended Sediment

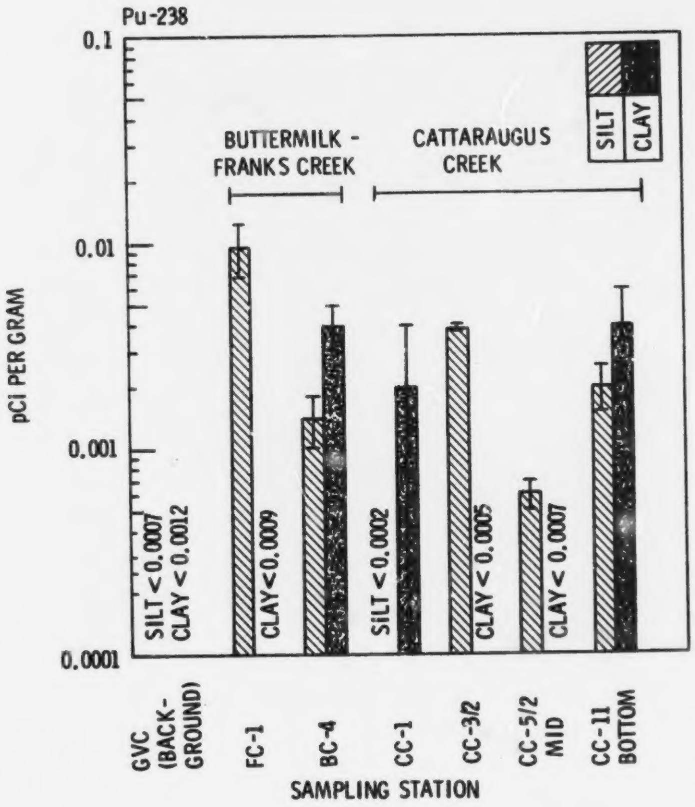

FIGURE 26. Plutonium-238 Associated with Suspended Sediment

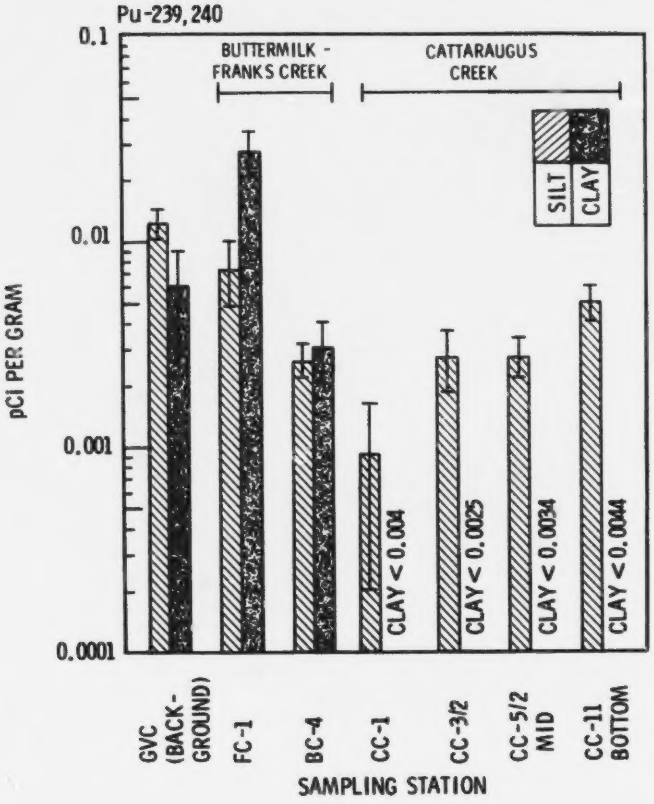

FIGURE 27. Plutonium-239,240 Associated with Suspended Sediment

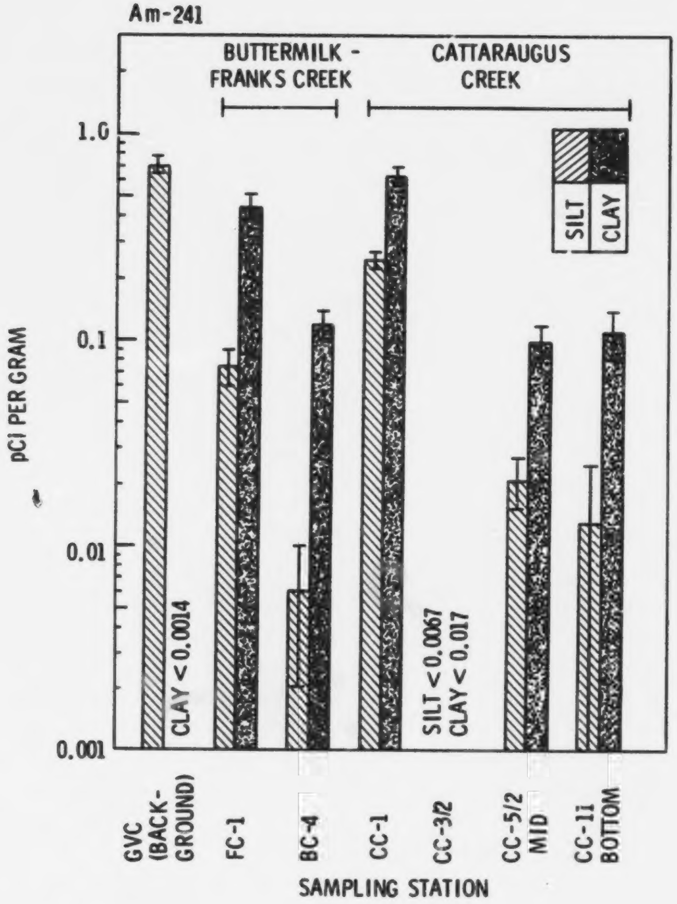

FIGURE 28. Americium-241 Associated with Suspended Sediment

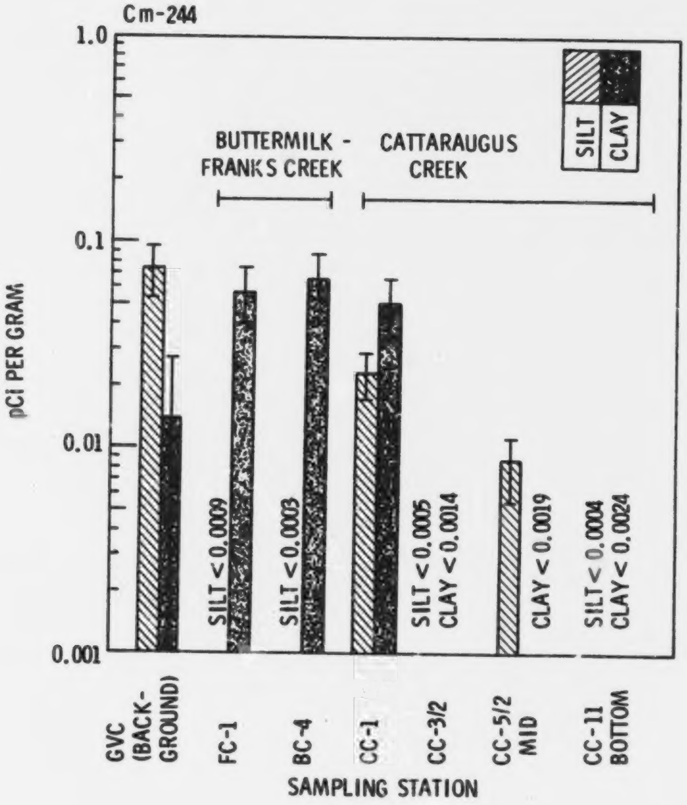

FIGURE 29. Curium-244 Associated with Suspended Sediment

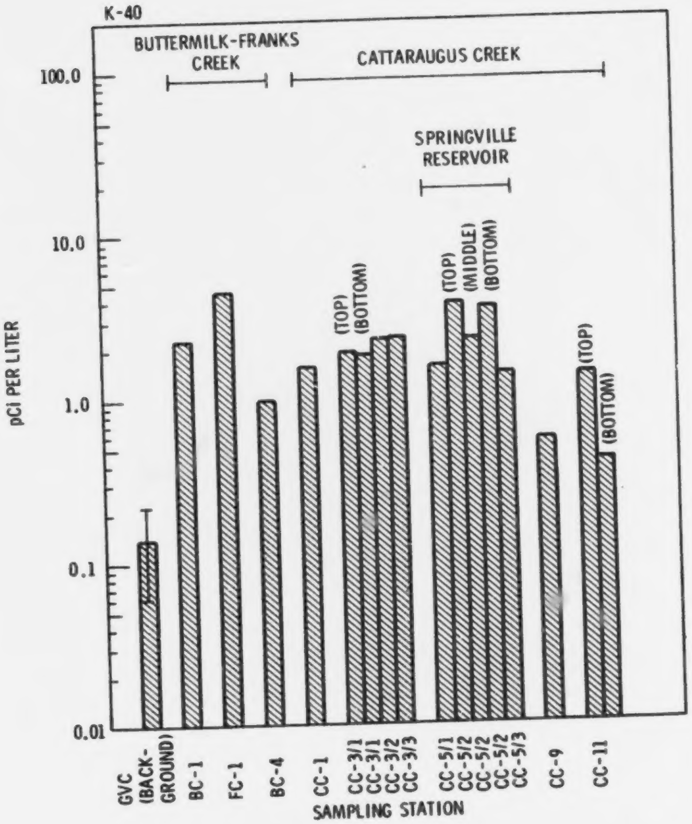

FIGURE 30. Dissolved Potassium-40

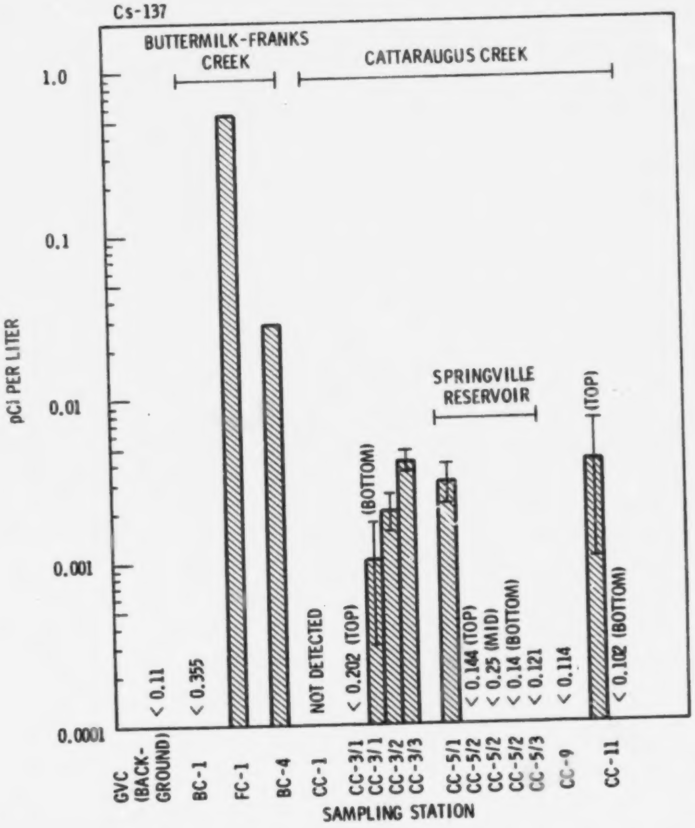

FIGURE 31. Dissolved Cesium-137

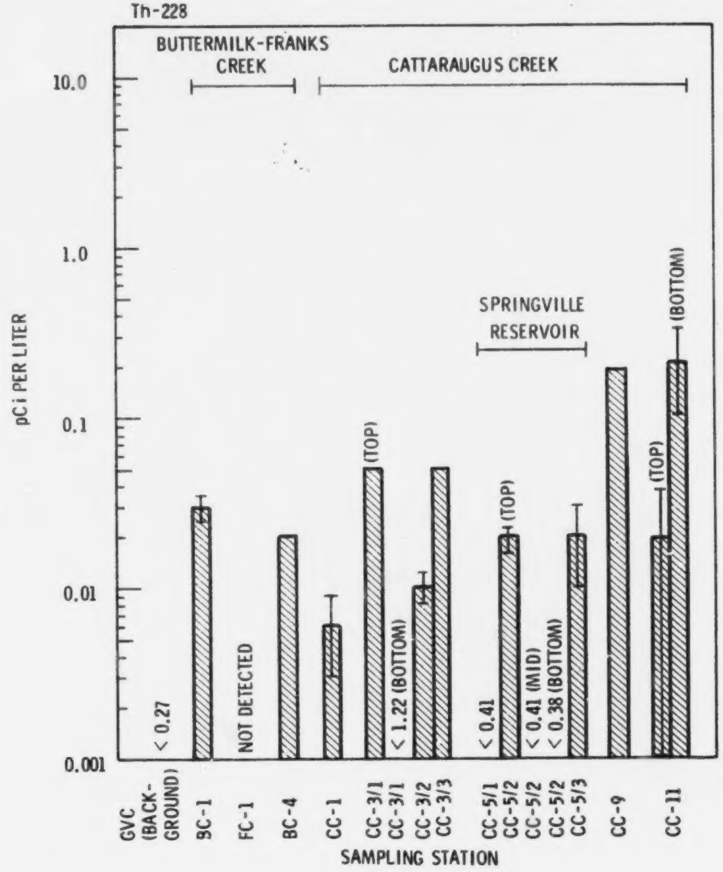

FIGURE 32. Dissolved Thorium-228

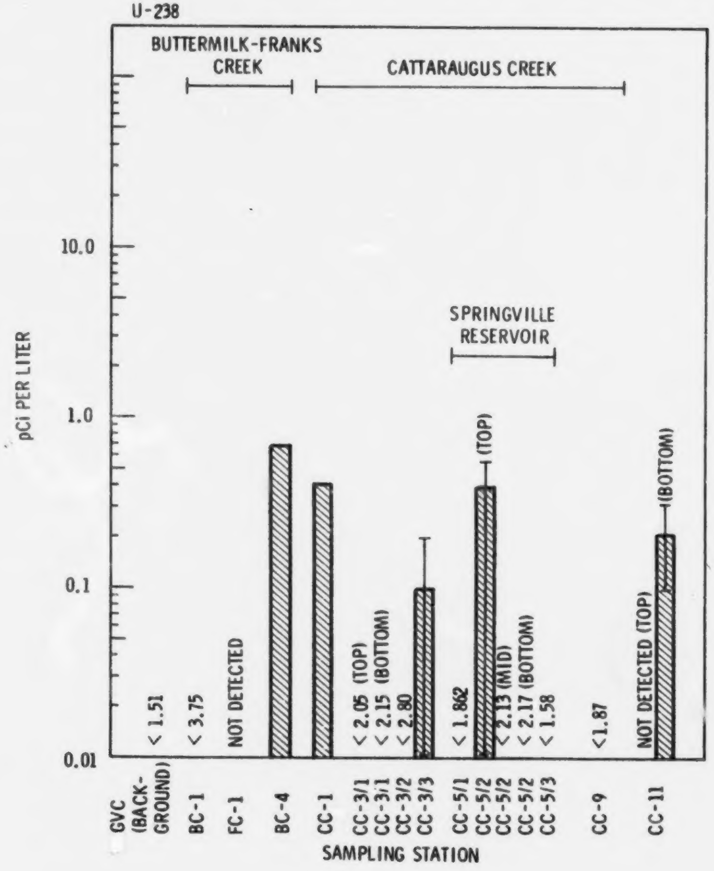

FIGURE 33. Dissolved Uranium-238

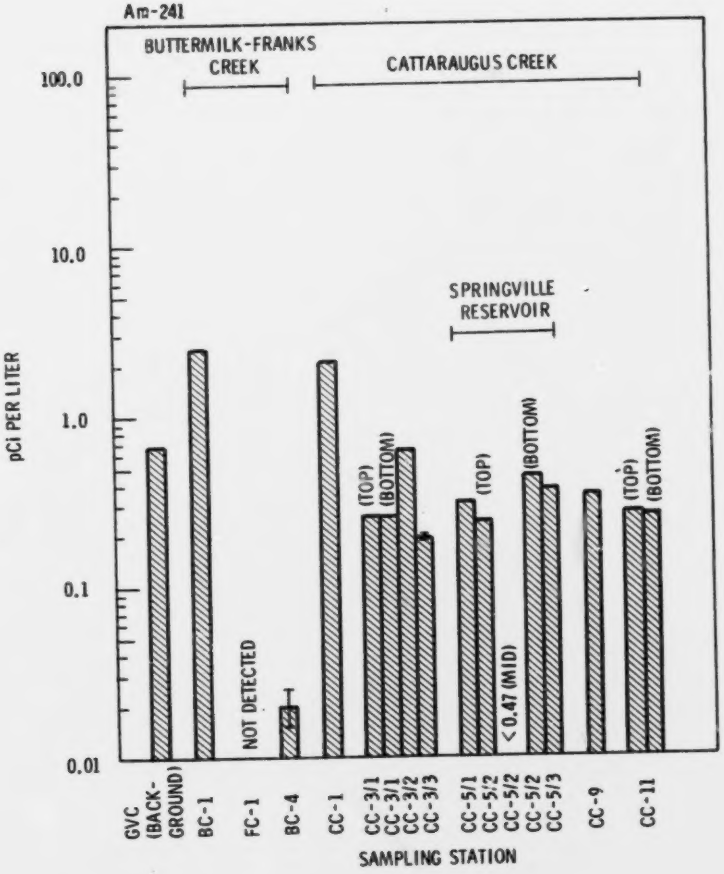

FIGURE 34. Dissolved Americium-241

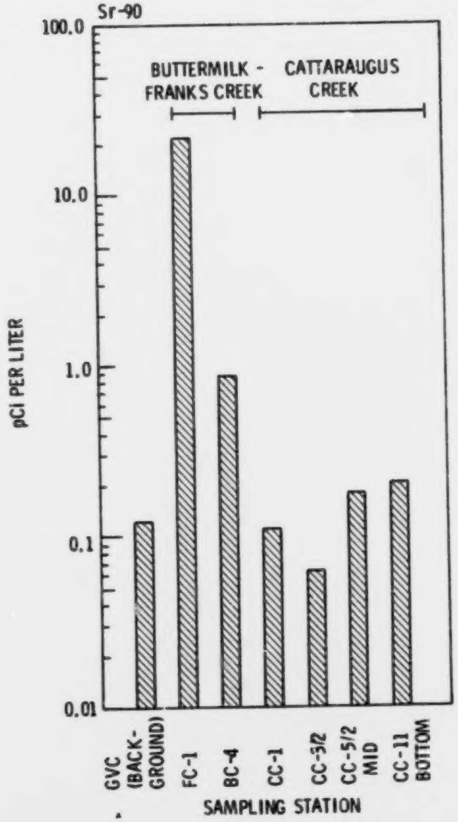

FIGURE 35. Dissolved Strontium-90

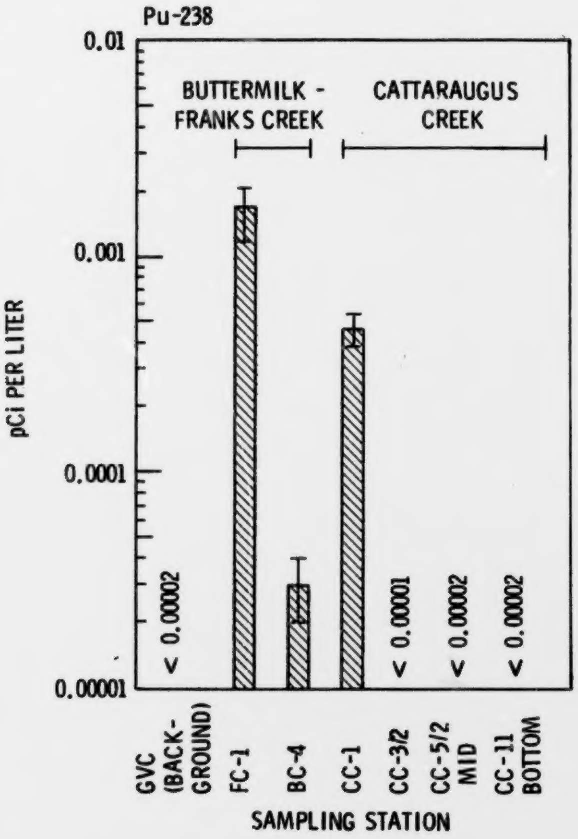

FIGURE 36. Dissolved Plutonium-238

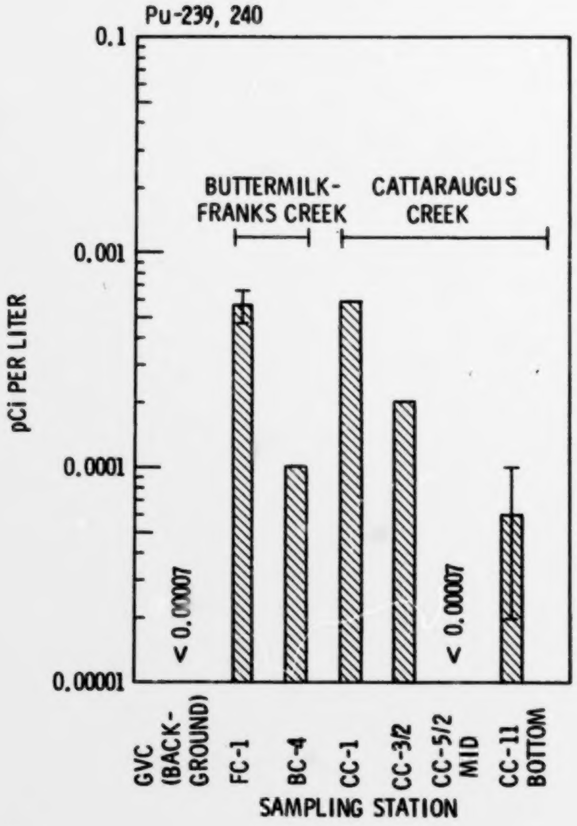

FIGURE 37. Dissolved Plutonium-239,240

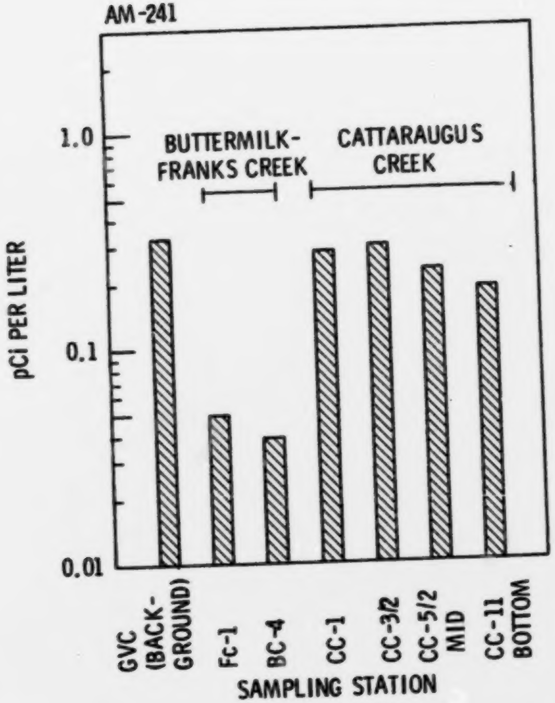

FIGURE 38. Dissolved Americium-241

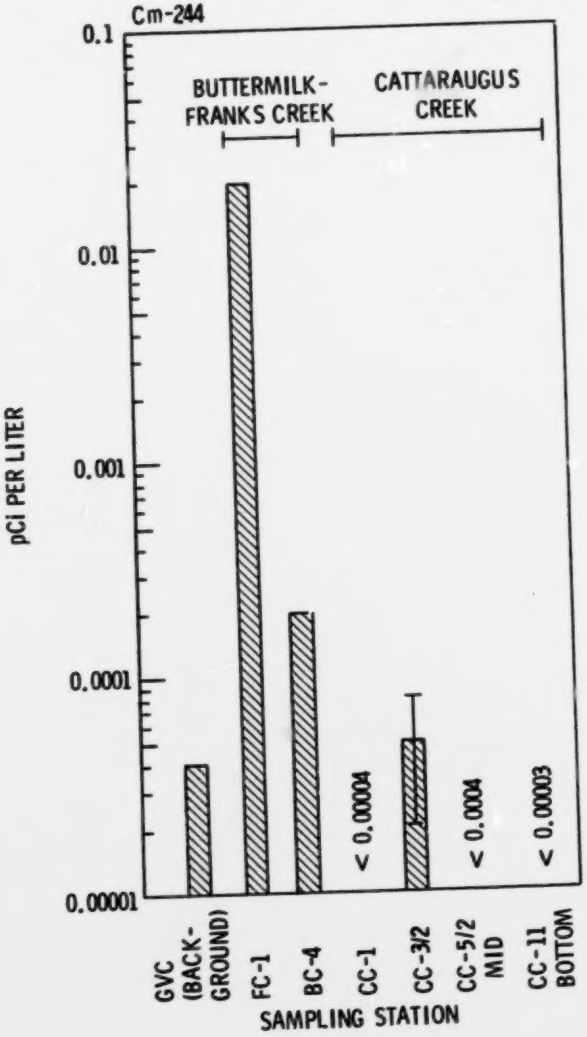

FIGURE 39. Dissolved Curium-244

three background stations (GVS, BC-1, and CC-1). The maximum activity level was detected at FC-1 (0.55 pCi/l) with the next highest level of BC-4 (0.028 pCi/l) about two miles downstream.

Three radionuclides, Strontium-90, Plutonium-238, and Curium-244, were found to have significantly higher activity levels at Franks Creek determined by radiochemical analysis. The maximum level of Strontium-90 (20.39 pCi/l) found at FC-1 was considerably higher than the 0.868 pCi/l found at BC-4. The levels at the remaining stations decrease to near background levels in Cattaraugus Creek. Curium-244 also had a significantly higher activity level at FC-1 (0.0197 PCi/l) as compared to the other stations analyzed. Both Plutonium-238 and Curium-244 were below detection and most of the downstream stations. Both plutonium-238 and 239, 240 had relatively high levels of activity at CC-1, which is the background station on Cattaraugus Creek together with relatively higher levels at FC-1.

Thorium-228 and Uranium-238 were both below detection at FC-1 and the background station GVC. Thorium-228 recorded the highest levels at the mouth of Cattaraugus Creek where 0.21 ± 0.02 pCi/l was detected at CC-11 (bottom sampling point). Uranium-238 is found only intermittently at the downstream stations.

Americium-241. Americium-241 was analyzed by both gamma counting (Figure 34) and radiochemical analysis (Figure 38). The isotope was found at much lower levels on the average at FC-1 and BC-4 as compared to the background stations and the others downstream on Cattaraugus Creek. The background stations at GVC, BC-1, and CC-1 all recorded relatively high levels of Americium-241. Below the confluence of Buttermilk and Cattaraugus Creeks the activity levels were nearly uniform.

The results of analysis for Americium-241 was the only set of data where it was possible to estimate the total dissolved concentration based on the sorption bed efficiency of the LVWS at several stations. Table 10 compares the results of both the gamma-counting and radiochemical analysis from the tables in Appendix D and the activity levels determined by LVWS efficiency calculations. The results from the Appendix D data tables are the sums of the

TABLE 10. Comparison of Analysis Results for Dissolved Americium-241 (pCi/liter). E is the calculated sorption bed efficiency.

	Gamma Ray Spectrometry		Radiochemical Analysis	
Station	Total from Table D.7	Total Based on LUWS Efficiency	Total from Table D.8	Total Based on LVWS Efficiency
GVC	0.67	0.76 (E=0.64)	0.327(a)	
BC-1	2.48	2.56 (E=0.77)	N.A.	
FC-1	Not detected		0.050	0.052(b) (E=0.47)
BC-4	0.02 (0.005)		0.038	0.024 (E=0.92)
CC-1	2.09	1.94 (E=0.89)	1.21(c)	1.28(c) (E=0.39)
CC-3/1 (Top)	0.26		N.A.	
CC-3/1 (Bottom)	0.26		N.A.	
CC-3/2	0.62	0.66 (E=0.70)	0.29	0.74 (E=0.17)
CC-3/3	0.19 (0.004)		N.A.	
CC-5/1	0.31		N.A.	
CC-5/2 (Top)	0.24		N.A.	
CC-5/2 (Mid)	<0.47		0.23	0.22 (E=0.93)
CC-5/2 (Bottom)	0.44		N.A.	
CC-5/3	0.37		N.A.	
CC-9	0.35		N.A.	
CC-11 (Top)	0.27		N.A.	
CC-11 (Bottom)	0.26		0.19	0.19 (E=0.94)

N.A = not analyzed

(a) Second aluminum oxide bed damaged during radiochemical analysis.

(b) Computed using resin bed efficiency.

(c) Filter activity level from gamma analysis used to compute total since filter damaged during radiochemical analysis.

activity detected on the individual beds and are minimum values. The activity level determined by efficiency calculations uses the percentage of radionuclide captured by the first and second beds of either aluminum oxide or resin to compute the total activity present in the water.

The activity levels determined by both analysis methods compare favorably overall. The minimum values of Americium-241 from gamma-counting are close to the estimated totals based on BLVWS efficiency at Stations GVC, BC-1, CC-1, BC-4, and CC-3/2 because the capture efficiency of the first aluminum oxide bed was high in each of the four cases which would tend to give the closer values. The results of the radiochemical analysis were very close at Stations FC-1, CC-1, CC-5/2 (mid), and CC-11 (bottom). The radiochemical results at station CC-3/2 yielded a minimum value of 0.29 pCi/g from the data tables which is much less than the total activity level of 0.74 pCi/g determined by efficiency calculations. Gamma-ray measurements yielded values of 0.62 pCi/g as a minimum and 0.66 pCi/g by efficiency calculations which compare closely to the total determined by radiochemical analysis.

The gamma analysis results at CC-1 and the radiochemical results at BC-4 and CC-5/2 (Mid) yielded slightly lower total activity levels from the efficiency calculations. In each case the calculated sorption efficiency was very high for the first bed which provided a total value slightly less than the minimum level determined by summation.

Tritium (Figure 40). The highest level of Tritium is found at station FC-1 with the lowest levels found at the background stations GVC, BC-1, and CC-1. The stations on Cattaraugus Creek downstream from the Buttermilk Creek outflow all show levels slightly above background. These trends indicate that the NFS site is a possible source of Tritium.

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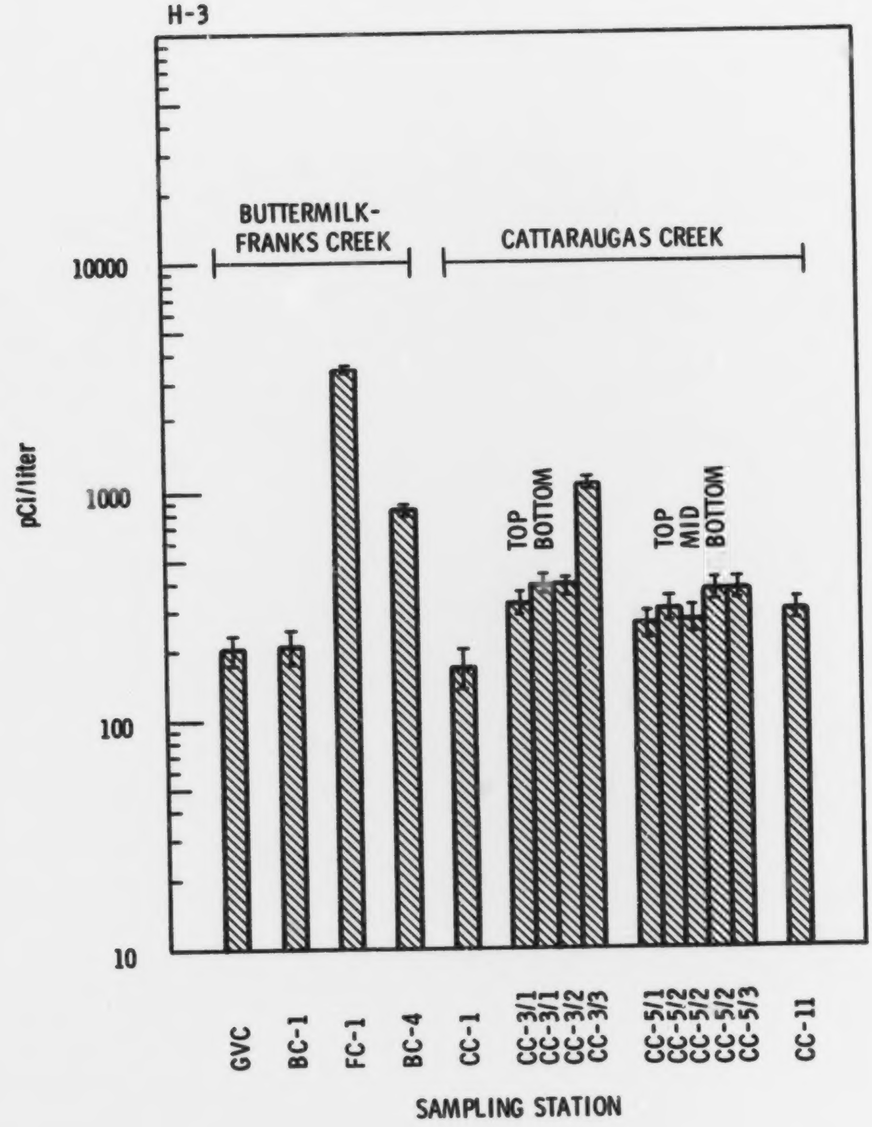

FIGURE 40. Dissolved Tritium

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CONCLUSIONS

In many cases the radiological results indicated comparatively high activity levels at the background stations GVC, BC-1 and CC-1 relative to the other locations. All the background stations are isolated from the surface water drainage system of the NFS site but they are in close proximity of the facilities. This may be a result of fallout from the stacks at the NFS site that has accumulated on the surrounding watershed surface and is periodically washed into the creek system by overland flow due to rainfall and snowmelt runoff. By this process higher background levels could be most anywhere upstream of the site and would depend to an extent on wind speed and direction. It seems probable that background activity levels near the NFS site are significantly higher than the more distant areas of the watershed.

The following conclusions are based on an evaluation of the radiological analysis results where the background stations are all in close proximity to the NFS site and could possibly be biased by fallout from the stacks:

1. The results of gamma-ray measurement for the bed sediment samples indicate that the NFS site is a possible source of Cesium-134 and Cesium-137. The results also indicate that relatively higher levels of Thorium-228, Thorium-232, and Uranium-235 may be accumulating in Springville Reservoir.
2. The results of the radiochemical analyses on the bed sediment samples indicates that the NFS site is a possible source of Strontium-90, Plutonium-238, Plutonium-239,240, and Americium-241.
3. The same dominant radionuclides found in the bed sediment of Buttermilk and Cattaraugus Creeks are found to be dominant in Lake Erie sediments.
4. The same dominant radionuclides found in the bed sediment samples are also found associated with the suspended sediment. Those radionuclides analyzed by gamma-ray measurement showed generally lower levels for the suspended sediment as compared to the bed sediment. The opposite is generally true for the alpha and beta-emitting

radionuclides analyzed radiochemically where levels associated with suspended sediment are slightly higher than those for bed sediment.

5. For both suspended and bed sediment samples the clay fractions had the highest activity levels overall followed by silt and then sand (bed sediment only).

6. Radionuclides were found more consistently in the bed sediment samples. Radionuclides were found much less frequently in the water than in either the bed sediment or suspended sediment samples.

7. The results of the gamma-ray measurement and radiochemical analysis of the LVWS filters and sorption beds indicate that the NFS site is a possible source of Cesium-137, Strontium-90, Plutonium-238, and Curium-244.

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APPENDIX A

LARGE VOLUME WATER SAMPLER (LVWS)

LARGE VOLUME WATER SAMPLER (LVWS)

The LVWS was developed at Pacific Northwest Laboratory (Silker et al. 1971) for the analysis of radionuclide concentration in seawater. The sampler has also been utilized to separate short-lived radionuclides from rainwater (Nielson and Wogman 1971) and analysis of Columbia River water for radionuclides discharged from the Hanford reactors (Robertson et al. 1973 and Perkins et al. 1976).

The LVWS was designed as a field sampler to process as much as 4000 liters of water in about 3 hours. Water is forced through the sample by pumping and the rate recorded by a flow meter (Figure 3). The sorption beds are stacked in the sample column below a set of filters. The filters remove the particulate matter and then the water is passed through the series of sorption beds before being returned to the source. The principle of the LVWS is based on the assumption that each sorption bed acts as a given number of theoretical plates and that the total concentration of the dissolved radionuclide can be determined by using the calculated collection efficiency between any two successive sorption beds.

An advantage of the LVWS sampling system is that the sampler concentrates the elements in the field. This increases the amount of the element available for analysis and by-passes the need for handling large volume samples.

The LVWS is applicable to flowing water as it takes an integrated sample over a 60 to 90 minute interval instead of an instantaneous sample. This would tend to dampen large variations in concentration due to moving water.

The total concentration of dissolved radionuclides is determined by the calculation of collection efficiency between any two sorption beds or more if desired. The method assumes that a fraction of the available solute is removed by each bed. When this approach is used the collection efficiency (E) between any two sorption beds can be determined by the following equation:

$$E_{(m,m+1)} = \frac{Nm - Nm+1}{Nm}$$

where

$E(m,m+1)$ = collection efficiency of bed Nm (first bed)

Nm = concentration of radionuclide in the m^{th} bed

$Nm+1$ = concentration of radionuclide in the m+1 bed

The calculated efficiency can be used to determine the concentration of radionuclide in the soluble phase, C_s:

$$C_s = \frac{Nm}{E(m,m+1)} + \sum_{1}^{m-1} N_{(m-1)}$$

where

C_s = concentration of the radionuclide in the soluble fraction of the water

$\sum_{1}^{m-1} N_{(m-1)}$ = sum of the concentrations of the radionuclide preceding bed m.

The total amount of radionuclide in the water, C_t, is the sum of the soluble fraction, C_s, and the particulate fraction, C_p, found on the millipore filters:

$$C_t = C_s + C_p.$$

APPENDIX B

SAMPLING STATION CROSS-SECTIONS

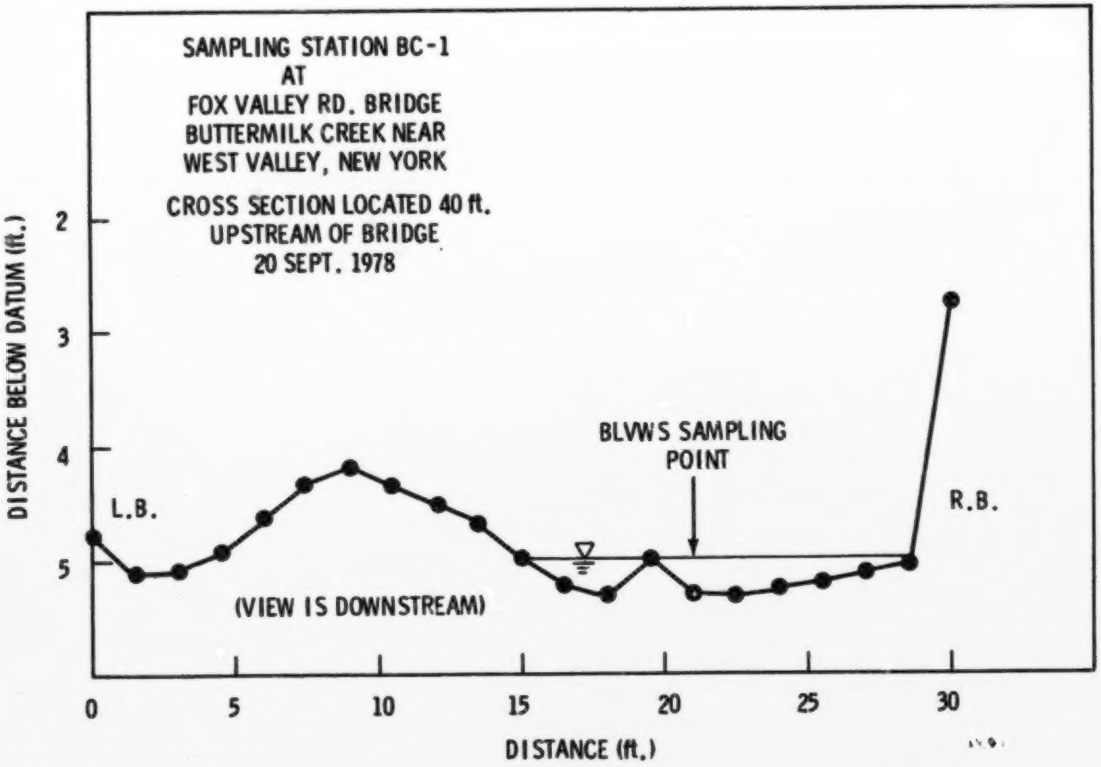

FIGURE B.1. Buttermilk Creek Sampling Station 1 Representing Background Conditions for Buttermilk Creek

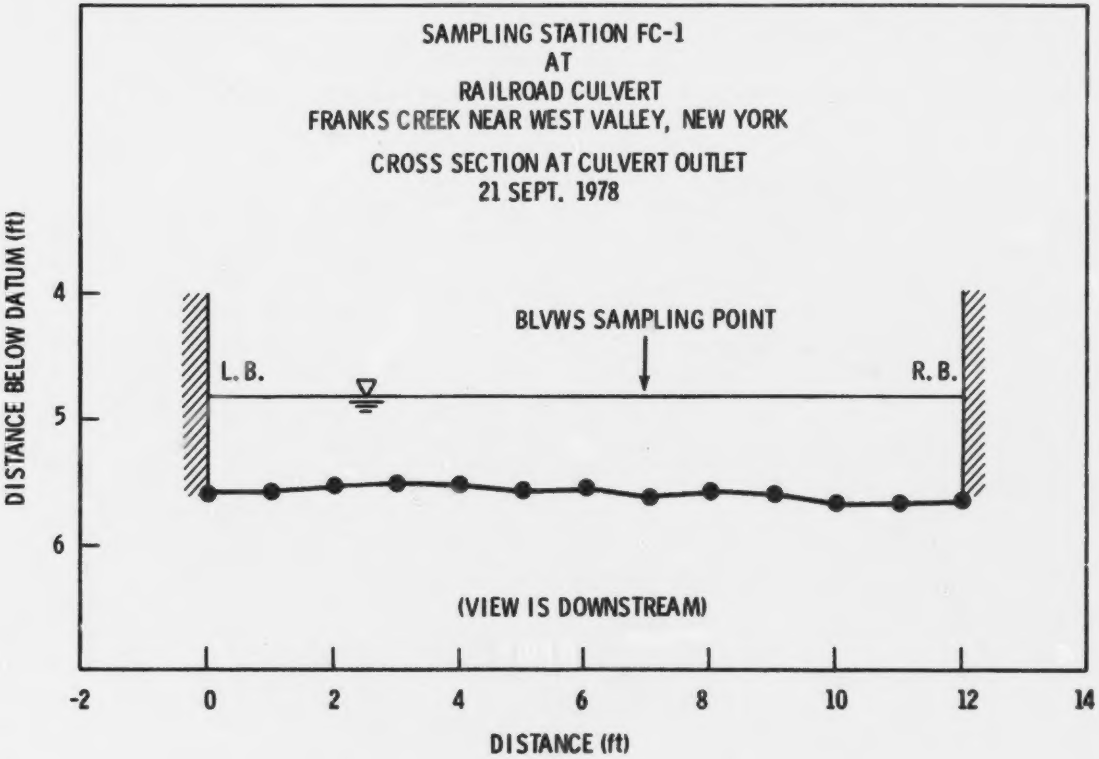

FIGURE B.2. Franks Creek Sampling Station at the Baltimore and Ohio Railroad Culvert

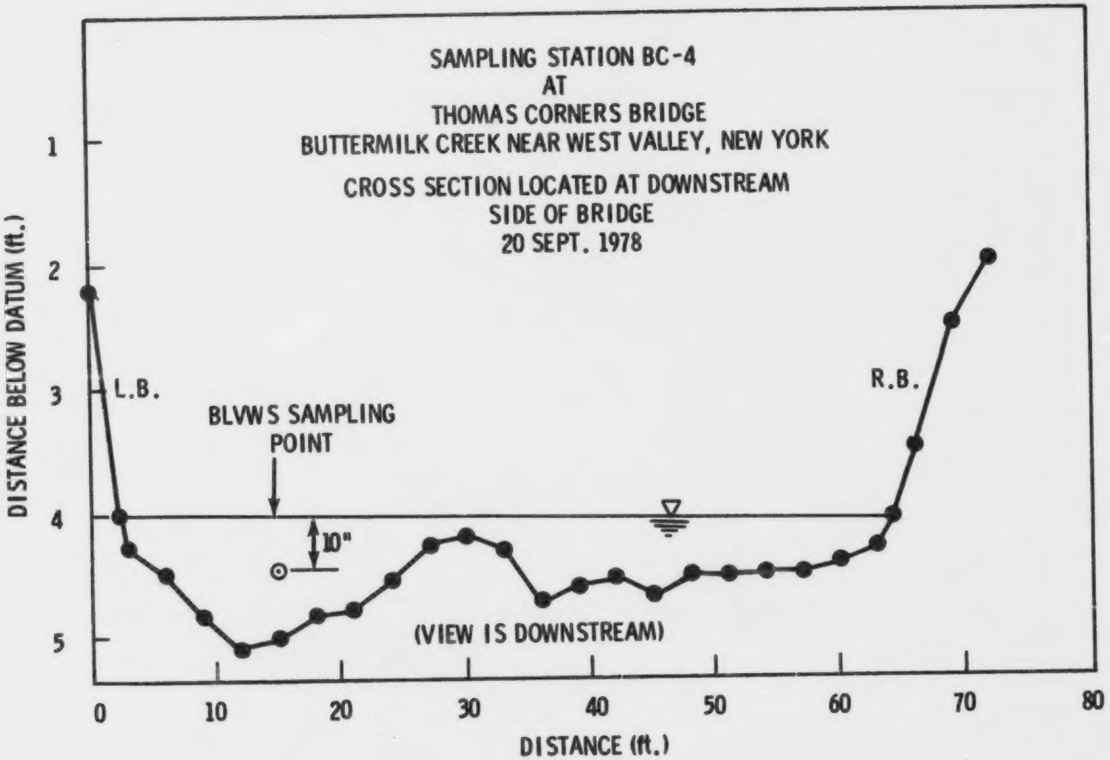

FIGURE B.3. Intermediate Buttermilk Creek Sampling Station 4

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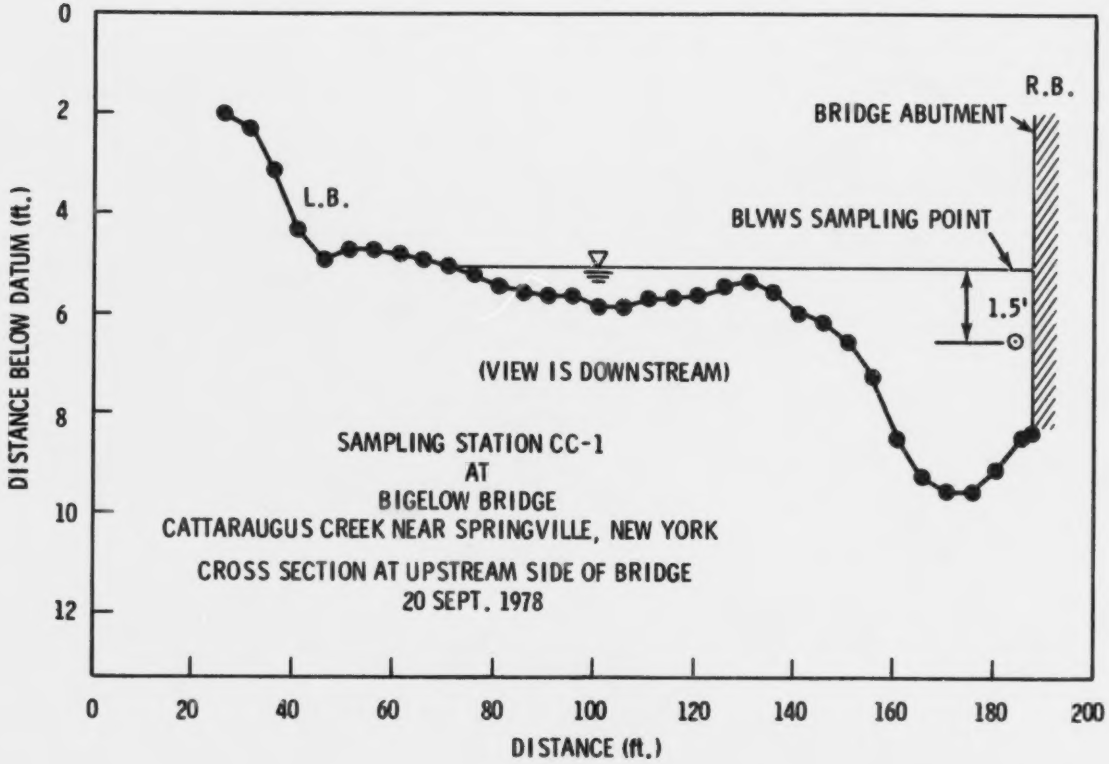

FIGURE B.4. Cattaraugus Creek Sampling Station 1 Representing Background Conditions for Cattaraugus Creek

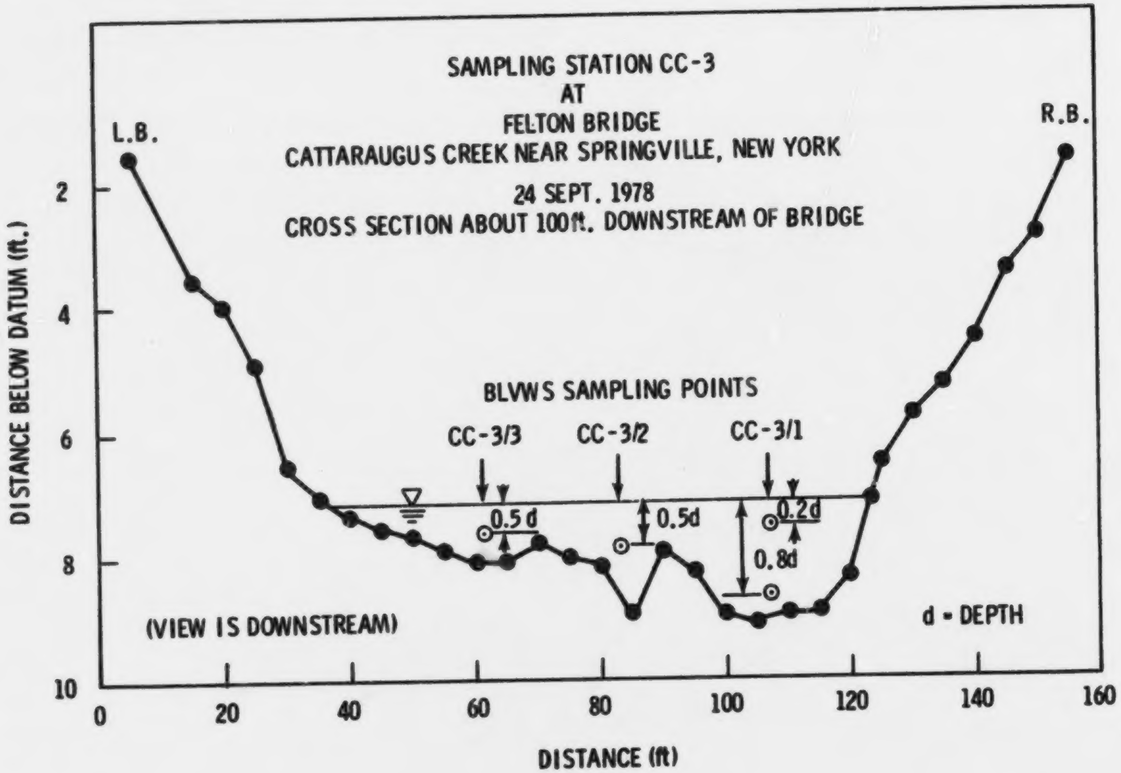

FIGURE B.5. Intermediate Cattaraugus Creek Sampling Station 3 Upstream of Springville Reservoir

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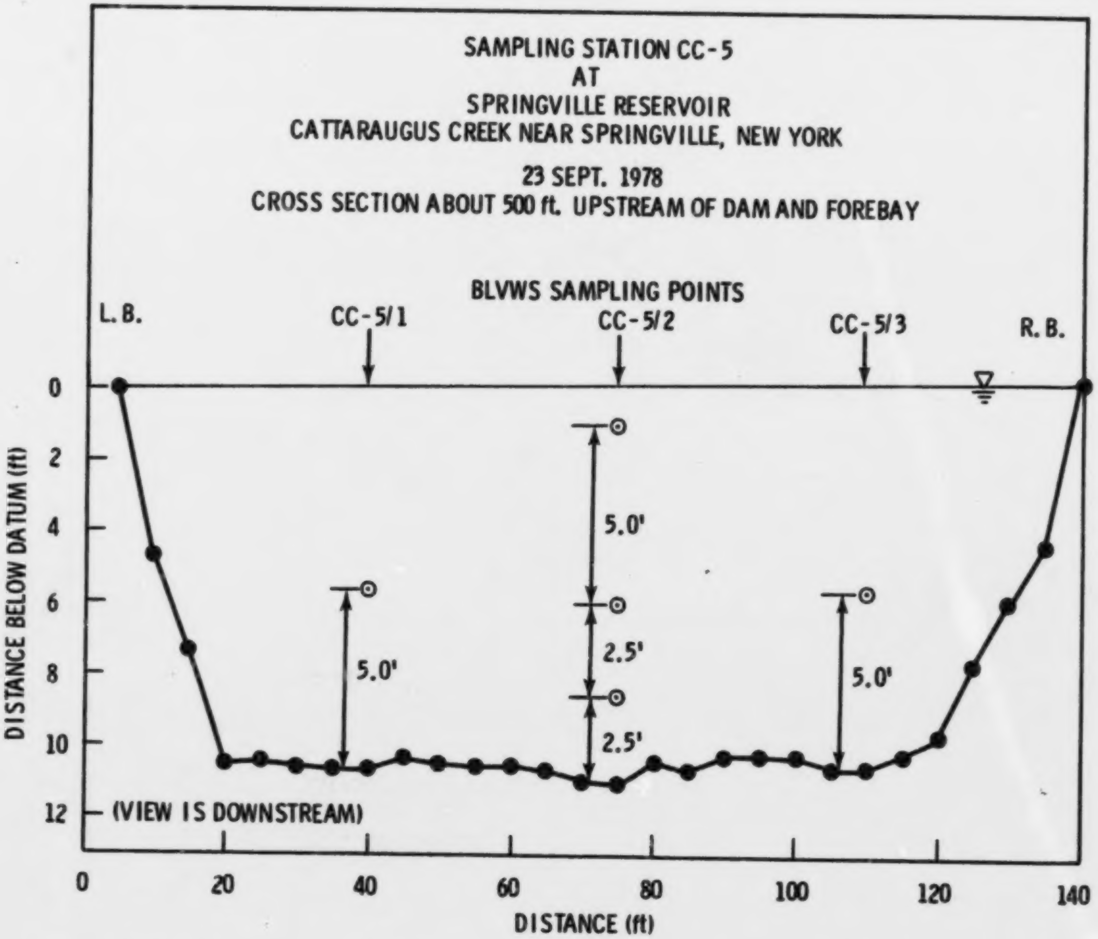

FIGURE B.6. Cattaraugus Creek Sampling Station 5 in Springville Reservoir

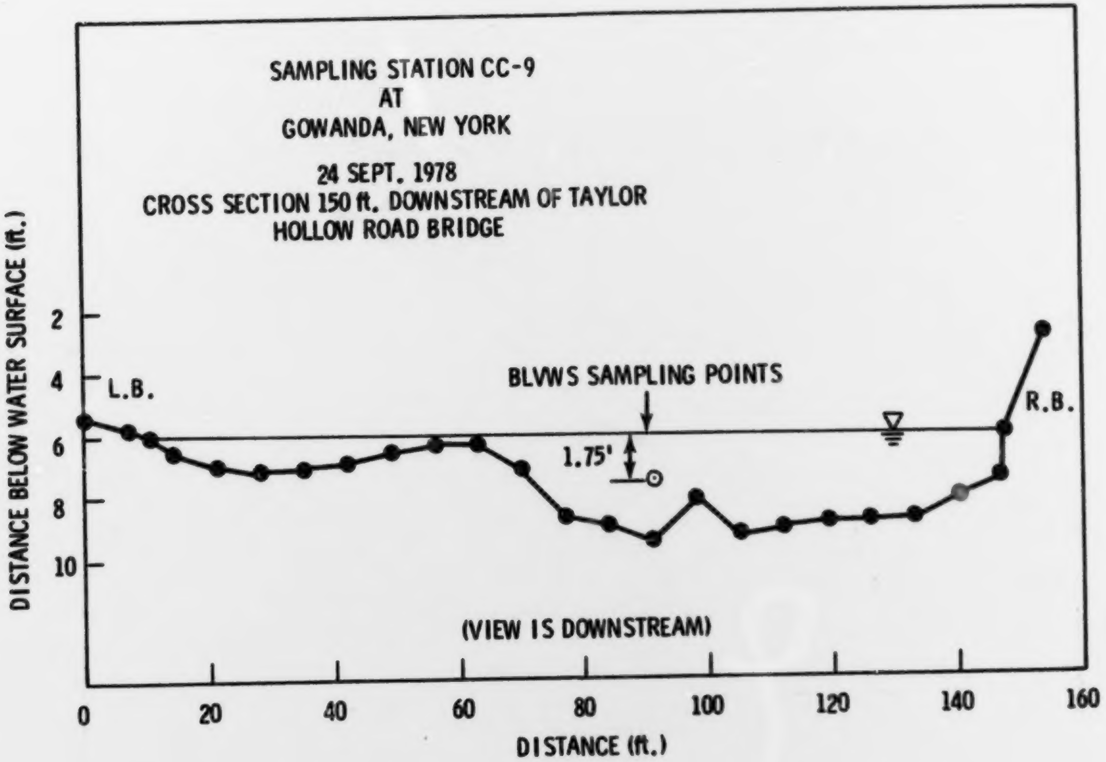

FIGURE B.7. Intermediate Cattaraugus Creek Sampling Station 9 at Gowanda, New York

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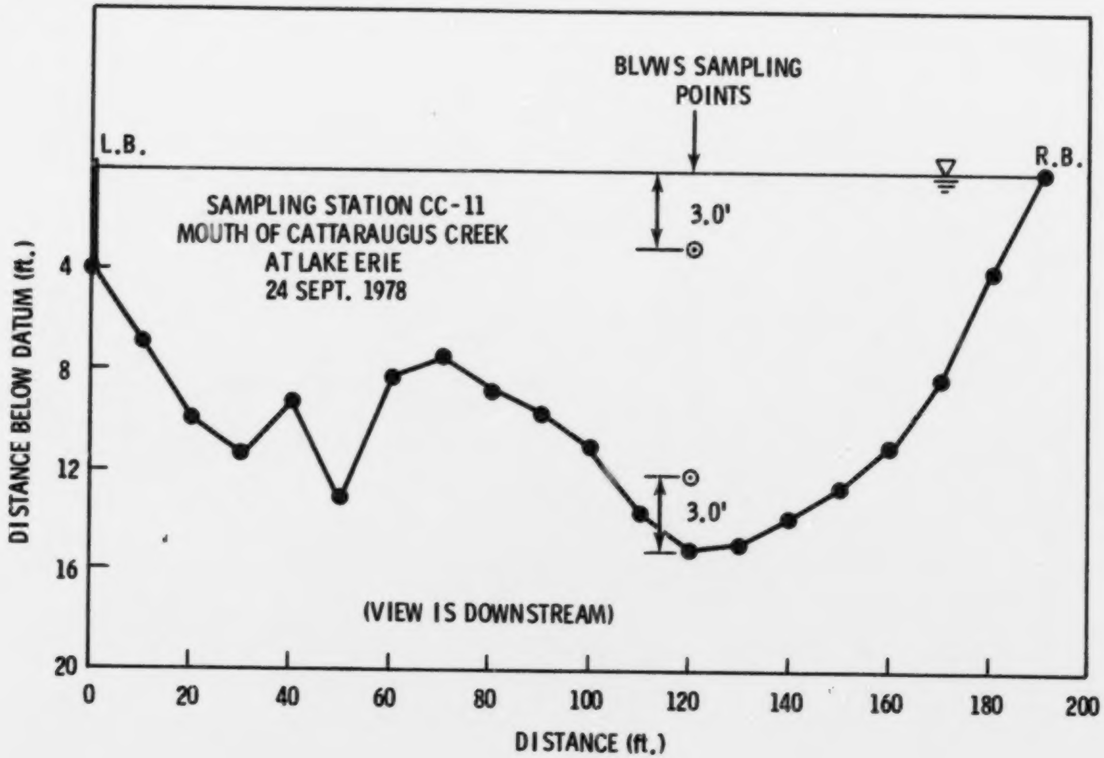

FIGURE B.8. Cattaraugus Creek Sampling Station 11 of the Mouth of Cattaraugus Creek

APPENDIX C

UNIVERSITY OF WASHINGTON
LABORATORY OF RADIATION ECOLOGY
METHODS OF ANALYSIS

UNIVERSITY OF WASHINGTON
LABORATORY OF RADIATION ECOLOGY

SUMMARY OF QUALITY CONTROL RESULTS OF RADIONUCLIDE ANALYSIS

INTRODUCTION

During the time period 1971-1979 the Laboratory of Radiation Ecology (LRE) has participated in internal, external, national, and international programs to compare measurements of radionuclides and stable elements. Standards as well as environmental samples have been interchanged between several laboratories including LRE and the results are reported here.

We have measured and reported about 160 intercomparison samples on about 20 radionuclides. The analysis included: gamma radionuclides by Ge(Li) diode and NaI(Tℓ) crystal methods , alpha radionuclides (by alpha spectroscopy methods for ^{238,239}Pu, ^{241}Am, ^{210}Pb, and ZnS screen and phototube counting for gross alpha radionuclides), beta radionuclides (by radiochemistry methods for ^{90}Sr, ^{131}I, by liquid scintillation method for tritium and by low background gas counting for gross beta radionuclides), and x-ray radionuclides (by radiochemistry methods for ^{55}Fe and x-ray proportional counting); measurements of trace elements have been made by NAA and AAS methods.

It has been our policy to treat the incoming standard samples identical to incoming normal environmental samples so that our internal reliability could also be checked. No special precautions have been taken in the measurement of the quality control samples.

MEASUREMENTS OF GAMMA-RAY EMITTING RADIONUCLIDES

Measurements of the concentrations of ^{241}Am and other gamma-emitting radionuclides in samples have been made using a 1 cm^2 Ge (intrinsic)(a) detector coupled to a 400-channel pulse height analyzer for ^{241}Am and two 7.3%(b) Ge(Li)(c) detector systems coupled to two 4096 channel pulse height analyzers with a PDP-5 computer data processing and reduction system. These detection systems have been cross calibrated with the two 5 x 5 Na(Tℓ) crystal detector systems which were used previously. In addition to the cross calibration between instruments, interlaboratory calibration of samples have been made continuously over the years to insure reliability in our measurements.

(a) Applied Detector Corporation, Menlo Park, California

(b) Absolute detection efficiency for 1.33 McV gamma rays relative to a 30% efficient NaI(Tℓ) detector

(c) Nuclear Diodes, Inc., Prairie View, Illinois (presently Edax International)

The absolute counting efficiency of each instrument was determined as a function of γ-ray energy by counting a series of standards prepared in the same geometry as that used to count the samples. Each standard was prepared and contained a known amount of a given radionuclide; these standard solutions were obtained from the N.B.S. or a commercial supplier, usually Amersham. An aliquot of each standard solution was added to an acrylic casting resin and homogenized by stirring until the resin set. Each encapsulated standard was thus uniformly distributed in the volume of the counting container (2' x 1/2", 2" x 1", 3" x 2") at a standard density of 1.1 g/cc and was a "permanent" standard for future calibration checks. The results of these calibrations are shown in Figure C-1 which shows the detector efficiencies as a function of gamma energy.

Since the cpm to dpm conversion factor, which was needed to calculate the absolute radionuclide concentrations of the sediment, biota and water samples from the counting data, was a function of several variables; (e.g., gamma-ray energy and bulk density) standards were prepared at a bulk density of 1.35 by adding NaCl to increase the density of the acrylic casting resin from 1.1 to cover the range normally found in our samples. The appropriate conversion factor for each sample (density) was then approximated by linear interpolation, between the values found for the 1.1 and 1.35 g/cc density standards.

The error that could result due to possible variation of the linear dependence assumption described above was estimated by considering the case where density changes gave logarithmic rather than linear changes in the correction factor. The maximum error that could result from a logarithmic instead of the assumed linear dependence was estimated by measuring the difference in the value of the two correction factors in samples which were at the extremes of sample densities encountered (0.6 and 1.6 g/cc). The difference found using the two correction factors was 7.3% for the sample geometry and density limit of the lowest energy radionuclide of ^{241}Am (most sensitive test). For radionuclide concentrations which were determined by using higher energy gamma-rays (>59.5 Kev) and for the majority of samples which were not at the extreme limits of the densities, the error which would arise due to this uncertainty was smaller than 7.3%.

The abundance of each γ-ray observed in the spectrum was used to calculate the concentration of the radionuclide present using a weighted mean concentration of each gamma peak and its associated error (Stevenson 1966). The error term associated with the counting are 2 S.D. errors based on propagated counting statistics.

The results of interlaboratory comparisons of concentration of the gamma-emitting radionuclides in the standards and environmental samples measured are shown in Table C-1.

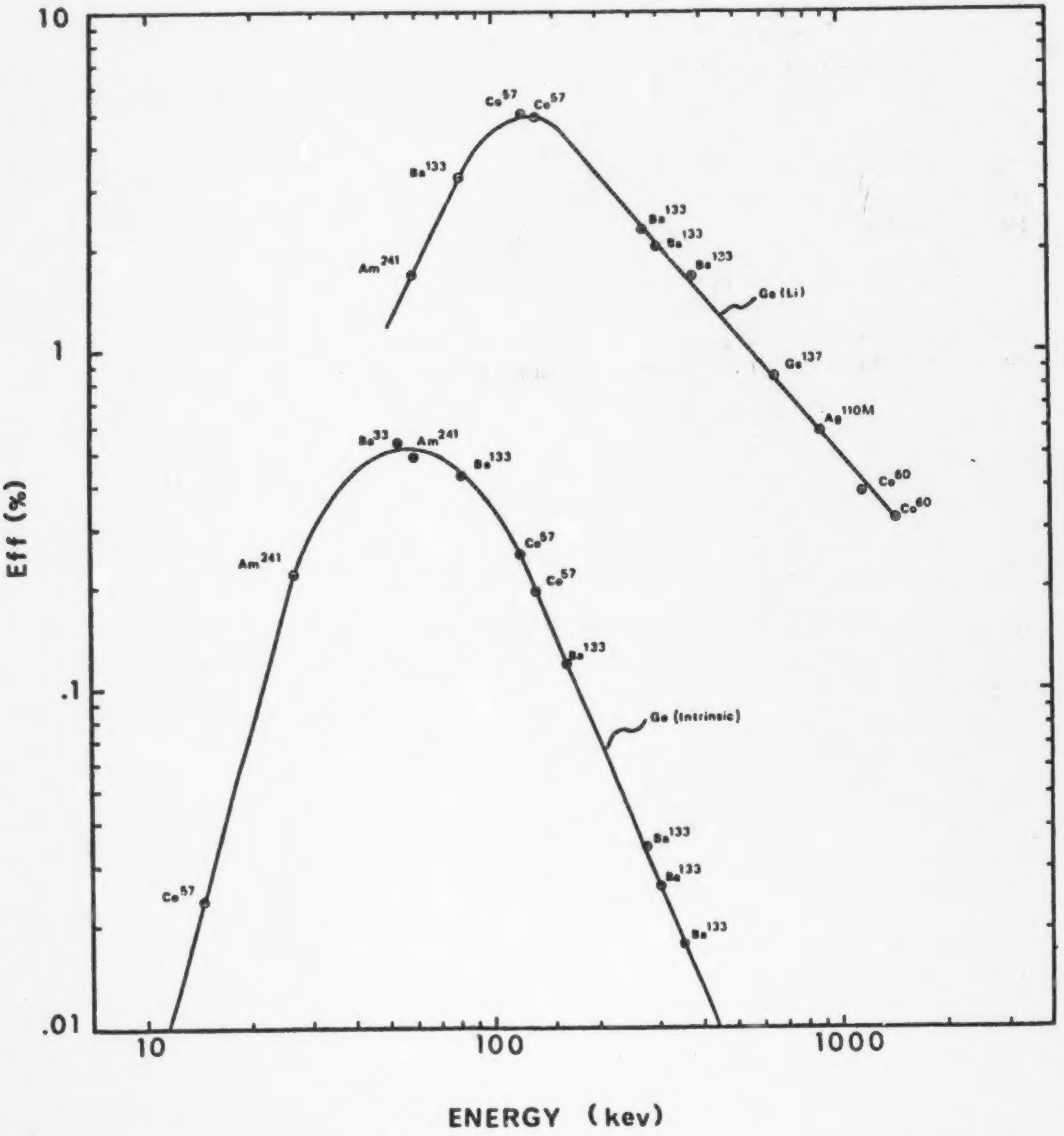

FIGURE C-1. Absolute Counting Efficiency of the Ge(Li) and Ge(Intrinsic) Detectors with Gamma-Ray Energy as Determined by Counting Radionuclide Standards Made to a Sample Density of 1.1 g/cc

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TABLE C-1. Results of Interlaboratory Comparisons of Gamma and Beta Radionuclides in Samples

Sample	Type	Date	Lab	^{90}Sr	^{95}Zr-^{95}Nb	^{106}Ru	^{134}Cs	^{137}Cs
35065 MA B-1	Clam Homogenate	June 76	IAEA	7.4 ± .8		4.3 ± .6	.29 ± .06	16.24 ± .4
			LRE	6.5 ± .3		5 ± 1	.25 ± .07	18.0 ± .4
35066 MA B-2	Sea Hare	June 76	IAEA	.31 ± .09			3.0 ± 1.4	4.1 ± .3
			LRE					4.8 ± .3
35052 Milk A-9	Milk	June 76	IAEA	.49 ± .02				2.14 ± .09
			LRE	.48 ± .04				2.40 ± .3
35000 AG-I-1	Seaweed	May 72	IAEA	10.0 ± .1	2.5 ± .3	137 ± 6	10.3 ± .3	75 ± 1
			LRE		2.21 ± .23	126 ± 4	8.5 ± .1	65.7 ± .2
35005 SD-B-1	Sediment	Jan 73	IAEA	13.8 ± .9		73 ± 2	9.6 ± .3	377 ± 6
			LRE			74.4 ± 1.2	9.6 ± .2	450 ± 2
35001 SW-I-1-19	Water	Jan 71	IAEA				1.7 ± .4	14.0 ± 2.0
			LRE				1.1 ± .5	16.6 ± 1.0
35002 SW-I-2-19	Water	Jan 71	IAEA			40 ± 5	26 ± 3	195 ± 14
			LRE			35.0 ± 5	28.2 ± 1.1	232 ± 4
35083 W-1	Water	1975	IAEA	3.55 ± .07				8.15 ± .12
			LRE	3.89 ± .15				7.6 ± .4
35084 W-2	Water	1975	IAEA	52.0 ± 1.0				119.3 ± 1.8
			LRE	54.0 ± 5				131.6 ± 3.4
35139	Diet	18 Feb 77	EPA	55 ± 8				45 ± 15
			LRE	69 ± 6				51 ± 3
35128	Diet	26 Nov 76	EPA	96 ± 14				46 ± 15
			LRE	112 ± 19				50 ± 12
35118	Diet	27 Aug 76	EPA					
			LRE	108 ± 9				31 ± 5
35075	Diet	Dec 75	EPA	125 ± 19				101 ± 15
			LRE	114 ± 23				104 ± 11
35053	Diet	Aug 75	EPA	101 ± 15				121 ± 18
			LRE	88 ± 2				119 ± 3
35038	Diet	Apr 75	EPA	150 ± 23				150 ± 23
			LRE	142 ± 4				155 ± 8
35028	Diet	Dec 74	EPA	175 ± 26				176 ± 26
			LRE	176 ± 2				193 ± 6
35018	Diet	Aug 74	EPA	198 ± 30				205 ± 31
			LRE					243 ± 6
35125	Milk	Nov 76	EPA	16 ± 5				11 ± 5
			LRE					9 ± 1
35110	Milk	Jul 76	EPA	0				75 ± 15
			LRE	5.8 ± 1				78 ± 7
35090	Milk	Mar 76	EPA	50 ± 7				25 ± 15
			LRE	59 ± 5				22 ± 2
35072	Milk	Nov 75	EPA	75 ± 11				75 ± 15
			LRE	68 ± 6				85 ± 2
35035	Milk	Mar 75	EPA	50 ± 8				
			LRE	51 ± 7				
35046	Milk	Jul 75	EPA	97 ± 14				70 ± 15
			LRE	89 ± 8				78 ± 4
35022	Milk	27 Nov 74	EPA	102 ± 15				101 ± 15
			LRE	10.9 ± .6				96 ± 8
35138	Water	4 Feb 77	EPA			151 ± 23	76 ± 15	39 ± 15
			LRE			105 ± 17	50 ± 7	29 ± 3
35154	Water	3 Jun 77	EPA			* *	*	*
			LRE			61 ± 3	38 ± 1	32 ± 2
35086	Water	20 Feb 76	EPA			336 ± 50	230 ± 35	361 ± 54
			LRE			263 ± 17	209 ± 2	368 ± 5
35124	Water	10 Oct 76	EPA					
			LRE			75 ± 17	82 ± 10	37 ± 5
35106	Water	18 Jun 76	EPA			79 ± 15	106 ± 16	53 ± 15
			LRE			27.4 ± 9	79 ± 3	40 ± 2
35067	Water	Oct 75	EPA			247 ± 37	349 ± 52	274 ± 41
			LRE			217 ± 19	325 ± 4	270 ± 5
35042	Water	Jun 75	EPA			325 ± 49	303 ± 46	378 ± 57
			LRE			293 ± 6	267 ± 7	369 ± 4
35031	Water	Feb 75	EPA				422 ± 63	472 ± 71
			LRE			<20	315 ± 7	398 ± 4
35021	Water	Oct 74	EPA			0 ± 15	481 ± 72	0 ± 15
			LRE			:30	485 ± 61	< 6
	Water	May 74	EPA			0 ± 15	0 ± 15	0 ± 15
			LRE			<1.9	.2	<.2

* EPA results not yet received

TABLE C-1. (contd)

^{144}Ce	^{40}K	^{154}Eu	^{155}Eu	^{60}Co	^{110}Ag	^{226}Ra	^{3}H
2.7 ± .5							
2.8 ± .5							
				166 ± 7			
<2				177 ± 2			
17.4 ± .9	39 ± 3		1.5 ± .2	2.0 ± .1	1.5 ± .1		
14.7 ± 2.8	36 ± 1	.11 ± .01	1.5 ± .1	1.8 ± .1	1.2 ± .1		
129 ± 5							
118 ± 4	11.2 1.5	.94 ± .15	4.44 ± .2				
				51.5 ± .8		3.64 ± .3	2.54 ± .09
				43.1 ± 1			
				2.53 ± .04		53.3 ± 4.5	45.3 ± 1.6
				2.30 ± .02			
	2670 ±401						
	2472 ± 83						
	2745 ±412						
	2583 ±237						
	2496 ±332						
	2414 ±362						
	2202 ±200						
	2352 ±353						
	1933 ±200						
	2216 ±333						
	2165 ±313						
	2619 ±393						
	2467 ±115						
	2389 ±358						
	2500 ±200						
	1510 ± 76						
	1403 ±106						
	1550 ±233						
	1356 ± 66						
	1529 ±229						
	1563 ±290						
	1549 ±233						
	1700 ±192						
	1514 ±228						
	1366 ±150						
	1495 ±224						
	1114 ±158						
				45 ± 15			
				39 ± 5			
				*			
				26 ± 1			
				209 ± 31			
				200 ± 4			
				24 ± 3			
				53 ± 15			
				48			
				271 ± 41			
				273 ±			
				350 ± 53			
				324 ± 12			
				437 ± 66			
				420 ± 14			
				0 ± 15			
				<6			
				0 ± 15			
				<.3			

[redacted]

TABLE C-1. (contd)

^{131}I	^{241}Am	^{125}Sb	^{140}Ba	^{51}Cr	^{65}Zn
		2.8 ± .5			
81 ± 15 109 ± 24					
0 <30			39 ± 15 72 ± 10		
115 ± 29			174 ± 31		
127 ± 19 112 ± 19			0 <35		
0 <40			145 ± 22 <200		
149 ± 22 154 ± 2			0 <50		
175 ± 26 200 ± 10			0 ± 15 <55		
216 ± 32 250 ± 10			207 ± 31 173 ± 6		
85 ± 5 84 ± 10			0 <20		
51 ± 15 48 ± 2			0 <12		
75 ± 15 70 ± 3			0 <26		
75 ± 15 13 ± 5			0 <56		
76 ± 15 116 ± 6			0 <20		
>.25			0 <38		
126 ± 19 119 ± 10			0 < 2		
				202 ± 30 173 ± 11	37 ± 15 37 ± 6
				*	*
				< 8	79 ± 4
				0 <18	445 ± 67 472 ± 11
				<10	55 ± 9
				0 <8	79 ± 15 75.1
				0 <18	250 ± 38 277 ±
				0 <20	327 ± 49 330 ± 6
				0 <30	472 ± 71 487 ± 4
				0 ± 15 <90	0 ± 15 <5
				349 ± 52 482 ± 30	0 ± 15 <.1

MEASUREMENTS OF BETA EMITTING RADIONUCLIDES

The beta-emitting radionuclides are measured using gas flow and liquid scintillation counting. The radionuclides which are measured in samples using the gas flow counters are ^{90}Sr and ^{131}I; radiochemical procedures for sample preparation are required. The results of these interlaboratory comparisons are shown in Table C-1.

MEASUREMENTS OF TRITIUM

The measurements for tritium in samples have been made by liquid scintillation methods using Instagel (Packard Instrument Co.) and a low background (4.6 c/m) detection system (Packard Tricarb). The mixture of water: Instagel was 8 cc. H_2O: 12 cc Instagel; these procedures were adopted from Sauzay and Schell (1971). Table C-2 shows that our tritium values are consistently within the measurement errors stated by EPA.

ALPHA SPECTROSCOPY MEASUREMENTS

Instrumentation and calibrations: the measurement of radioactivity by alpha spectroscopy was made by using eight 300 mm^2 silicon surface barrier diodes. Each of the two counting systems available for use consisted of four diodes, preamplifiers and amplifiers routed through a router-mixer to each of four 128-channel quadrants of a 512-channel multichannel analyzer (MCA). The MCA memory was dumped into both typwriter (digital) and graphical (analog) outputs after typical counting periods of 800 minutes. The detector amplifier gain was adjusted to 9 keV/channel. The resolution of the diodes (FWHM) was 20 keV or better. Background count rates of the four diodes used for plutonium and uranium analysis were 0-8 counts/800 minutes under each of the observed alpha peaks. Background count rates of the four diodes used for polonium analysis were typically 5 counts/800 minutes/peak.

The absolute disintegration rate of the isotopes of plutonium, uranium and ^{208}Po in the plated samples was determined by computing the ratio of the count rate observed for each isotope to the count rate for a secondary standard of known disintegration rate; corrections were made for background count rate, alpha particle branching ratios, and any impurities in the radiochemical spikes.

The disintegration rate of the secondary standards of plutonium was determined by similar calibrations with a standard ^{236}Pu solution supplied by the AEC Health and Safety Laboratories (HASL). The reliability of the plutonium calibration was verified by the agreement between the concentrations of plutonium found by this laboratory and those found by other laboratories in an interlaboratory standard solution of $^{239,240}Pu$ and ^{238}Pu concentrations measured by LRE in seaweed and sediment samples supplied by the International Atomic Energy Agency (IAEA) were also in agreement with the values recommended by the IAEA. The results of both these calibrations are shown in Table C-3.

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TABLE C-2. Results of Interlaboratory Comparison of Tritium in Water Samples

Sample	Type	Date	Lab	^3H
35132	Water Cross Check	Dec. 76	EPA	2300 ± 1049
			LRE	2287 ± 65
---	Water Cross Check	Oct. 76	EPA	58 ± 5
			LRE	55 ± 9
---	Water Cross Check	Aug. 76	EPA	3100 ± 1080
			LRE	3200 ± 104
---	Water Cross Check	Apr. 76	EPA	1776 ± 1024
			LRE	1793 ± 42
35096	Water solution standard	May 76	EPA	No values available
			LRE	7.15 ± 0.26; 27.4 ± 0.08; 312.3 ± 0.14; 221.2 ± 3.1
35078	Water Cross Check	Dec. 75	EPA	1002 ± 972
			LRE	1000 ± 52
35050	Water Cross Check	Aug. 75	EPA	3200 ± 1083
			LRE	3337 ± 67
35036	Water Cross Check	Apr. 75	EPA	1499 ± 1002
			LRE	1540 ± 60
35026	Water Cross Check	Dec. 74	EPA	3395 ± 1095
			LRE	3449 ± 30
35017	Water Cross Check	Aug. 74	EPA	1438 ± 933
			LRE	1447 ± 74
---	Water Cross Check	May 74	EPA	2673 ± 1050
			PRE	2717 ± 38
35146	Water Cross Check	Apr. 77	EPA	1760 ± 1023
			LRE	1702 ± 41

TABLE C-3. Results of Interlaboratory Analysis of Samples for $^{239,240}Pu$

A. Standard Reference materials, solutions, soils

Sample	Type	Date	Laboratory	$^{239,240}Pu$	Comments
35005 SD-B-1	sediment	January 73	IAEA	960 ± 30	^{238}Pu 42 ± 4
			LRE	950 ± 70	^{238}Pu (N.D.)
35000 AG-I-1	seaweed	January 72	IAEA	27000 ± 100	Pu 3800 ± 100
			LRE	23400 ±1000	Pu 3100 ± 100
35083 W-1	water	1975	IAEA	3.21 ± 0.05	
			LRE	2.8 ± 0.3	
35149 R-2	water	March 77	EPA	1110 ± 100	Round robin study
			LRE	990 ± 44	
Soil - 2	soil	January 71	EPA(avg.)	0.30	Cross check study
			LRE	0.16 ± 0.18	
Soil - 3	soil	January 71	EPA(avg.)	2.24	Cross check study
			LRE	0.51 ± 0.13	"High fired" soil
Soil - 4	soil	April 71	EPA(avg.)	1735 ±1220	Cross check study
			LRE	1547 ± 955	Nevada test soil
Soil - 5	soil	May 71	EPA(avg)	208 ± 117	Cross check study
			LRE	96 ± 54	"High fired" soil
Soil - 6	soil	June 71	EPA(avg)	18164 ±2800	Cross check study
			LRE	21433 ± 306	Pacific Islands soil
35047 NBS #4350	river sediment	1975	NBS	.038 ± .003	
			LRE	.042 ± .018	
LLL #110	std. solution	1973	LLL	1303 ± 28	
			LLL	1320 ± 20	
			LLL	1265 ± 5	
			MCL	1255 ± 15	
			MCL	1272 ± 6	
			LFE	1330 ± 27	
			LRE	1273 ± 64	
			EIC	1207 ± 54	

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TABLE C-3. (contd)

B. Collection on Joint Cruises.

Sample	Type	Laboratory	^{239,240}Pu Particulate	^{239,240}Pu Total	Avg.±S.D.	Dev. %
Bikini Atoll - 1972						
Lagoon water - STA B-2	surface	LLL[a]	28 ± 2	107 ± 4	91.3±19	+17
		PRNC[a]		98 ± 7		+ 8
		LRE[b]	30 ± 2	69 ± 4		-24
" - STA.B-15	surface	LLL	4.7 ± .6	66 ± 2	49.3±16	+34
		PRNC	--	49 ± 4		-.6
		LRE	3.1 ± .2	33 ± 5		-33
" - STA B-15	29m	LLL	5.6 ± .6	60 ± 3	57.0±21	+ 5
		PRNC	--	76 ± 7		+33
		LRE	6.4 ± .1	35 ± 2		-38
" - STA B-25	surface	LLL	9.7 ± .9	79 ± 3	73.0±8.5	+ 8
		PRNC	--	67 ± 4		- 8
		LRE	--	--		
" - STA B-25	50m	LLL	--	64 ± 3	95 ±44	-33
		PRNC		127 ± 9		+33
		LRE	--	--		
" - STA B-30	surface	LLL	--	--		
		PRNC		55 ± 3	42 ±18	+30
		LRE	2.5 ± .3	29 ± 3		-30

TABLE C-3. (contd)

B. Collection on Joint Cruises (cont'd.) Sample	Type	Date	Laboratory	$^{239, 240}Pu$ Particulate	 Total	 Avg.±S.D.	Dev. %
			Bikini Atoll - 1972 (cont'd.)				
Lagoon water - STA B-30	45m		LLL	--	--		
			PRNC	--	81 ± 2		+15
			LRE	29 ± 1	60 ± 3		-15
Bomb Crater water - STA C-3	surface		LLL	10 ± 1	38 ± 1	44.0±16	-14
			PRNC	--	32 ± 1		-27
			LRE	13.6 ± .3	62 ± 2		+40
" - STA C-3	44m		LLL	22 ± 1	35 ± 2	33 ± 3	+ 9
			PRNC	--	--		
			LRE	24 ± 2	31 ± 3		- 9
" - STA C-8	surface	1972	LLL	--	47 ± 4	59 ±12	-13
			PRNC	--	68 ± 3		+25
			LRE	14.6 ± .6	48 ± 8		-11
Deep ocean water - STA D-1	300m		LLL	--	51 ± 6	28 ±32	+82
			PRNC	--	5 ± 1		-82
			LRE	--	--		
" - STA D-7	surface		LLL	--	3.5 ±0.2	3.45±.07	+ 1
			PRNC	--	--		
			LRE	0.13±0.06	3.4 ±1.2		- 1
			Eniwetak Atoll - 1972				
Lagoon water ½ mi. off Leroy	Surface		LLL		18 ± .9	15 ± 4	+20
		½ flood ½ ebb }	LRE	0.45 ±0.1	12 ± 3.5		-20
" Enewetak Dock	Surface	?	LLL	--	1.6 ± 0.2	1.43±.25	+12
		flood	LRE	0.47 ±0.1	1.25± 0.2		-12
" Japtan	Surface	?	LLL	--	2.8 ± 7	2.14±.65	+30
	Surface	flood	LRE	0.62 ±0.1	1.5 ± 0.2		-29
	Surface	ebb	LRE	1.15 ±0.2	2.14± 0.4		0

TABLE C-3. (contd)

B. Collection on Joint Cruises (cont'd.)

Sample	Type	Date	Laboratory	$^{239, 240}$Pu		Avg.±S.D.	Dev. %
				Particulate	Total		
Eniwetak Atoll - 1972 (cont'd.)							
Lagoon water - Runnit Dock	Surface	?	LLL	--	43.6 ± 1.4	57.1 ± 19	-23
		½ flood ½ ebb	LRE	26.9 ±1.4	70.6 ± 6.6		+23
" - 200 yds off Runnit	15m	?	LLL		77.0 ± 3.1	69.1 ± 11	+11
		flood	LRE	34.3 ±0.9	61.1 ± 2.6		-11
Crater water - Mike Crater	33m	?	LLL	--	1510 ± 60	844 ±941	+79
		ebb	LRE	164 ±5	179 ± 6		-79
" " "	Surface		LLL	--	19.0 ± 0.8	20.0±1.5	-5
		flood	LRE	11.13 ±0.6	21.1 ± 5.6		+5
Washington Coastal Waters - 1976							
Coastal Water JDF-8 N 48° 27.1; W 124°45.2"	Surface		BNWL	0.14 ± .01)	(0.69±0.12)	- Sequim Bay	
			LRE	< .06	0.34±0.1		
			LRE		<0.59		
			LRE (batch)		0.5 ±0.25		
JDF-8 (50m) N 48° 30.0'; W 126° 46.0'	Surface		BNWL	0.09 ±0.01	0.12±0.04		
			LRE	<0.008	0.14±0.14		
			LRE	0.061±0.045	0.19±0.19		
			LRE (batch)		< .44		
HOH-5 mi. N 47°40'; W 124°33.6'	Surface		BNWL	0	0.18±0.05		
			LRE	0.03	0.26±0.26		
			LRE (batch)		< .4		

TABLE C-3. (contd)

C. Internal Comparisons of BLVWS and Batch Methods Sample	Type	Depth	Method	$^{239,240}Pu$ Particulate	Total	Avg.±S.D.	Dev. %
		Bikini Atoll - 1976					
Lagoon Water	STA B-3	Surface	Batch	--	55.1 ± 17.4	48.9 ± 9	+13
			BLVWS	16.7 ± 1.0	42.7 ± 2		-13
"	"	29 m	Batch	--	72.2 ± 8.2	67.5 ± 7	+ 7
			BLVWS	50.2 ± 3.6	62.9 ± 4		- 7
"	STA B-8	Surf	Batch	--	41.8 ± 9.7	34.7 ±10	+20
			BLVWS	< .3	27.7 ± 3.7		-20
"	"	17m	Batch	--	32.6 ± 6.0	31.7 ± 1.3	+ 3
			BLVWS	2.17 ± .17	30.8 ± 2.4		- 3
"	"	40m	Batch	--	28.3 ± 4.4	28.9 ± .9	- 2
			BLVWS	3.71 ± .5	29.5 ± 4.5		± 2
"	STA B-15	Surf	Batch	--	61.3 ± 22.4	37.5 ±20	+63
			BLVWS	1.6 ± .2	23.5 ± 1.4		-37
			BLVWS	1.9 ± .2	27.8 ± 1.4		-25
"	"	17m	Batch	--	36.2 ± 4.7	34.5 ± 3	+ 5
			BLVWS	1.7 ± .2	32.7 ± 3		- 5
"	"	37m	Batch	--	44.1 ± 9.3	41.3 ± 4	+ 7
			BLVWS	2.3 ± .2	38.4 ± 4.3		- 7
"	STA B-25	Surf	Batch	--	76.7 ± 9.7	59.7 ±24	+28
			BLVWS	2.17 ± .14	42.8 ± 5.7		-28
"	STA B-32	Surf	Batch	--	40.6 ± 9.4	32.9 ± 7	+18
			BLVWS	6.6 ± .4	28.2 ± 2		-14
			BLVWS	6.1 ± .5	29.9 ± 1		- 9
"	"	17m	Batch	--	45.6 ± 5	40.2 ± 8	+13
			BLVWS	5.0 ± .6	34.7 ± 3		-13
"	"	33m	Batch	--	44.6 ± 6	43.5 ± 1.6	+ 3
			BLVWS	10.2 ±1.6	42.4 ± 3		- 3

---

[a] Samples by LLL and PRNC were collected by the "Batch" method at a time which was usually before the long time BLVWS collections

(continued)

[b] The LRE and BNWL samples were collected continuously over a time period at 2-4 hours using the BLVWS sampler which separated the particulate and soluble fractions; in 1972 two sorption beds of Al_2O_3 were used and in 1976 four Al_2O_3 beds were used.

[c] The LRE "Batch" collections were made during the BLVWS pumping to compare directly the two methods. The plutonium method of Wong et al. (1976) was employed.

The disintegration rate of the ^{232}U spike was determined by comparison of the activities of aliquots (in quadruplicate) of the ^{232}U spike and a ^{238}U standard solution electroplated simulatneously onto platinum discs. The ^{238}U solutions used for the standard were prepared by dissolving precisely weighted amounts of 99^{+}% pure ^{238}U "D-38" metal supplied by the LLL.

The ^{208}Po spike was supplied as a radiochemical standard solution by the Amersham/Searle Corporation and has been calibrated several times between 1970-1975 by intercomparing the rdioactivity of plated samples with National Bureau of Standards (NBS), Battelle Northwest Laboratory (BNWL), and the LLL.

Replicate determinations of the plutonium concentration in a dissolved sediment (section 8-10 cm of core B-2) from Bikini Lagoon were performed to provide an estimate of the analytical precision of the radiochemical procedures used for plutonium analysis. The quantity of sediment (dry wt.) in each aliquote processed was 3.19 g. The chemical yield calculated from the counting data for these samples ranged from 22.6 to 40.8%. The precision for the ^{239,240}Pu determination was 5.3% of the mean concentration of 2. S.D. for the six analyses. The precision for ^{238}Pu measurement was 11% of the mean at 2. S.D. for the six analyses. The higher deviation about the mean for ^{239}Pu replicates is probably due to poorer counting statistics (average of 124 counts/800 minutes in the 238 peak vs. 5000 counts/800 minutes in the ^{239,240}Pu peak); all six ^{238}Pu concentrations found were within 2. S.D. counting errors of each other (Marshall 1975).

Quality control: problems of sample contamination were addressed by the inclusion of spiked reagent blanks with groups of samples. From several such reagent blanks, no significant contamination problem was detected. An evaluation was made of the interferences which might occur from natural and bomb-produced, alpha-emitting radionuclides in the Bikini Atoll samples.

In the plutonium and uranium procedures radium is removed along with the calcium in the chemical separation process. Isotopes of radon which might interfere are short-lived and, being gases, present no problems. Decontamination factors of greater than 1000 are reported by Butler (1968) for the removal of americium, thorium and neptunium from the final uranium samples, and similarly high decontamination factors are reported for the removal of curium and californium (Butler 1965), using TlOA separation procedures. Although Berkelium is unusual among the transamericium actinides, in that it can exist in the 4+ oxidation state (and therefore may not be separated from plutonium and uranium), it can not exist in the 4+ state in the 8 $\underline{M}$ HNO_3 - H_2O_2 solution which was used to maintain the oxidation states of $\overline{Pu}$ (VI) in the initial extraction step of the TlOA procedure (Keller 1971). The TlOA ion exchange method used in these separations provided high decontamination factors for the removal of uranium from the plutonium fraction (>300:1) and for the removal of plutonium from the uranium fraction (>1000:1) (Butler 1968).

[redacted]

Because no information was found concerning the plating efficiency of radionuclides which would interfere in the analysis of polonium by the plutonium procedures used in this work, solutions with known quantities of ^{241}Am, ^{242}Pu, ^{232}U, ^{228}Th, ^{224}Ra and ^{208}Po were prepared and plated as previously described.

Table C-3 shows the interlaboratory comparison results of plutonium analysis. Results of the January 1976 interlaboratory comparison of ^{210}Po in solution was Environmental Protection Agency (EPA) 164.4 ± 4.5, LRE 166 ± 5.4. The chemical procedures have been checked by the comparisons between duplicate standard samples re: IAEA, NBS, EPA. Interlaboratory comparisons between actual samples which have been exchanged are given for the results of the McClelland Laboratory (MCL) and LRE data. Of the 17 biota samples which were measured as "duplicates" six results fell outside the estimated errors of the two laboratories. It is not clear as to which laboratory was correct or whether both laboratories were correct and inhomogeniety existed in the samples. Of the five soil samples analyzed in 1971, one value was clearly outside the estimated errors of the two laboratories; and one value had a large measurement error (Nervic and Ray 1973).

A comparison of actual water samples collected in 1972 by Puerto Rico Nuclear Center (PRNC), LLL, and LRE using difference collection and analysis methods is also shown in Table C-3. Discrete samples were collected at a single time (5-10 min) by LLL and PRNC, while LRE collected samples by continuous filtration over a time period of 2-4 hours. Noshkin (1974) has shown at Enewetak that variations in ^{239,240}Pu concentrations as great as a factor of 3 can exist at certain locations over one tidal cycle.

The samples measured at Bikini, where large changes in the concentrations of Pu at different locations have been observed, compared reasonably well between the three laboratories. Values are certainly within a factor of 2 at the concentration level of pCi/1000ℓ. In fact most of the values are within 30%. Comparisons can also be made between the values of the particulate fraction of the total measured by both LLL and LRE shown in Table C-3. Most of these values are within the reported counting errors.

The direct comparison of the Batch and BLVWS methods are shown by the internal LRE intercomparisons in Table C-3. The Batch method used in these comparisons was by Wong et al. (1976); the BLVWS method employed four sorption beds of Al_2O_3 whereas only two beds were used in 1972 at Bikini and Enewetak. The Batch method and BLVWS methods compared well (average about 13% difference) on most samples with the Batch method giving slightly higher values than the BLVWS method.

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APPENDIX D

RESULTS OF RADIOLOGICAL ANALYSIS
BY UNIVERSITY OF WASHINGTON

TABLE D.1. Concentration of Radionuclides in the Channel Bed Sediment of Buttermilk and Cattaraugus Creek Sampling Stations. Results of gamma-ray measurements. Values in parentheses are two standard deviations of the propagated counting error.

STATION: BC-1

Radionuclide Concentration - Bed Sediment
pCi/g

	Sand	Silt	Clay	Composite
Sample Weight, Analysis (g)	67.5	67.5	4.9	
Sample Weight, Field (g)	1732.5	82.5	4.94	1819.94
Be-7				
K-40	11.7(1.4)	11.9(1.4)	59.3(34.9)	11.9(1.5)
Mn-54				
Cr-51				
Co-60				
Zn-65				
Nb-95				
Ru-103				
Ru-106				
Rh-101				
Rh-102				
Sb-125	0.031(0.03)	0.03(0.03)		0.031(0.03)
Cs-134	0.05(0.02)	0.04(0.03)		0.05(0.02)
Cs-137		0.10(0.04)		0.005(0.002)
Ce-144				
Eu-152				
Eu-155		0.19(0.08)		0.009(0.004)
Pb-210				
Bi-207				
Ra-226	0.61(0.05)	0.91(0.06)		0.62(0.05)
Th-228	0.67(0.07)	0.97(0.07)	3.05(1.61)	0.69(0.07)
Th-232	0.73(0.14)	0.88(0.14)	4.17(3.61)	0.75(0.15)
U-235	0.10(0.04)	0.10(0.04)	2.02(1.05)	0.11(0.04)
U-238	0.86(0.49)	1.48(0.47)		0.89(0.49)
Am-241				

TABLE D.1. (contd.)

STATION: EB

Radionuclide Concentration, pCi/g

	Sand					
	Coarse	Medium	Fine	Silt	Clay	Composite
Sample Weight, Analysis (g)	80	67.5	66.3	50	25	
Sample Weight Field (g)	230	155	58.5	532	83	1058.5
Be-7						
K-40	14.5(1.3)	13.6(1.5)	12.0(2.1)	15.2(1.8)	35.7(3.0)	13.6(1.54)
Mn-54						
Cr-51				83.1(52.5)		41.6(26.3)
Co-60	0.59(0.05)	0.64(0.06)	0.39(0.08)	0.54(0.06)	1.61(0.15)	0.52(0.067)
Zn-65			0.80(0.75)			0.048(0.045)
Nb-95						
Ru-103	2.14(2.0)					0.47(0.44)
Ru-106						
Rh-101	0.04(0.03)				0.09(0.05)	0.016(0.011)
Rh-102	0.12(0.06)			0.15(0.06)		0.101(0.04)
Sb-125		0.84(0.07)	0.42(0.08)	0.62(0.07)	2.55(0.17)	0.665(0.064)
Cs-134	1.24(0.06)	0.85(0.06)	0.42(0.07)	0.66(0.06)	2.58(0.14)	0.96(0.068)
Cs-137	72.1(0.5)	43.7(0.4)	21.3(0.5)	29.5(0.4)	112.0(1.0)	47.4(0.48)
Ce-141						
Ce-144					0.67(0.62)	0.054(0.05)
Eu-152						0.011(0.01)
Eu-155						
Pb-210						
Bi-207	0.13(0.05)	0.13(0.05)			0.33(0.11)	0.21(0.07)
Ra-226	0.78(0.08)	0.71(0.08)	0.57(0.1)	1.03(0.08)	1.3(0.17)	0.93(0.09)
Th-228	0.84(0.1)	0.82(0.09)	0.65(0.12)	1.14(0.1)	2.07(0.2)	1.08(0.109)
Th-232	0.56(0.32)	1.01(0.26)	0.51(0.35)	0.82(0.27)	1.81(0.61)	0.86(0.31)
U-235	0.18(0.06)	0.16(0.06)		0.2(0.06)	0.2(0.11)	0.18(0.06)
U-238	1.63(0.72)	1.33(0.69)	0.88(0.85)	1.22(0.74)	1.94(0.91)	1.37(0.756)
Am-241	0.25(0.21)					0.06(0.05)

TABLE D.1. (contd.)

STATION: FC-1

Radionuclide Concentration - Bed Sediment
pCi/g

	Sand	Silt	Clay	Composite
Sample Weight, Analysis (g)	80	67.5	25.0	
Sample Weight, Field (g)	1207	531	53	1791
Be-7			41.0(25.5)	1.23(0.765)
K-40	14.1(2.0)	15.5(2.2)	39.2(3.4)	15.3(2.1)
Mn-54				
Cr-51				
Co-60	0.44(0.08)	0.45(0.09)	1.91(0.14)	0.49(0.08)
Zn-65				
Nb-95				
Ru-103				
Ru-106			33.7(3.44)	1.01(0.10)
Rh-101		0.06(0.05)		0.018(0.015)
Rh-102			0.25(0.20)	0.008(0.006)
Sb-125	0.44(0.10)	0.51(0.11)	2.67(0.18)	0.53(0.11)
Cs-134	0.47(0.07)	0.52(0.08)	2.81(0.146)	0.56(0.075)
Cs-137	27.7(0.50)	28.6(0.60)	134.0(0.90)	31.2(0.54)
Ce-141				
Ce-144				
Eu-152			0.15(0.14)	0.005(0.004)
Eu-155				
Pb-210				
Bi-207	0.11(0.06)	0.11(0.07)	0.33(0.11)	0.12(0.065)
Ra-226	0.51(0.09)	0.84(0.11)	1.74(0.18)	0.65(0.10)
Th-228	0.59(0.11)	1.04(0.13)	2.31(0.22)	0.78(0.12)
Th-232	0.46(0.32)	0.62(0.40)	2.22(0.63)	0.57(0.36)
U-235	0.07(0.06)	0.16(0.07)	0.57(0.14)	0.12(0.07)
U-238	0.91(0.59)	0.82(0.72)	3.57(1.52)	0.96(0.66)
Am-241				

TABLE D.1. (contd.)

STATION: BC-4

Radionuclide Concentration - Bed Sediment
pCi/g

	Sand	Silt	Clay	Composite
Sample Weight, Analysis (g)	80	67.5	3.1	
Sample Weight, Field (g)	1627.5	287	15	1929.5
Be-7				
K-40	10.6(1.14)	11.3(1.30)	34.7(18.0)	10.9(1.3)
Mn-54				
Cr-51				
Co-60	0.14(0.03)	0.19(0.05)		0.15(0.03)
Zn-65				
Nb-95				
Ru-103				
Ru-106				
Rh-101		0.05(0.02)		0.008(0.008)
Rh-102	0.08(0.04)	0.07(0.06)		0.08(0.04)
Sb-125		0.25(0.05)	1.81(0.60)	0.056(0.014)
Cs-134	0.21(0.03)	0.27(0.04)	1.87(0.48)	0.24(0.04)
Cs-137	11.2(0.20)	15.2(0.27)	108.0(2.8)	12.8(0.2)
Ce-141				
Ce-144				
Eu-152				
Eu-155	0.068(0.067)			0.057(0.056)
Pb-210				
Bi-207		0.05(0.03)		0.008(0.005)
Ra-226	0.45(0.05)	0.77(0.06)	2.62(1.0)	0.52(0.06)
Th-228	0.48(0.06)	0.93(0.08)	3.28(1.08)	0.58(0.07)
Th-232	0.31(0.17)	0.90(0.21)	6.17(2.54)	0.46(0.20)
U-235	0.07(0.03)	0.11(0.04)		0.08(0.03)
U-238	0.57(0.32)	0.63(0.42)		0.57(0.33)
Am-241				

TABLE D.1. (contd.)

STATION: CC-1

Radionuclide Concentration - Bed Sediment
pCi/g

	Sand	Silt	Clay	Composite
Sample Weight, Analysis (g)	80	33.8	1.8	
Sample Weight, Field (g)	665	59.8	1.75	726.55
Be-7			93.(79.2)	0.23(0.19)
K-40	9.4(1.09)	11.5(2.0)	27.7(16.9)	9.6(1.2)
Mn-54				
Cr-51				
Co-60		0.07(0.06)	0.90(0.87)	0.008(0.007)
Zn-65				
Nb-95				
Ru-103				
Ru-106				
Rh-101				
Rh-102		0.05(0.04)		0.004(0.003)
Sb-125				
Cs-134				
Cs-137	0.19(0.04)	0.98(0.09)	14.8(1.7)	0.29(0.05)
Ce-141				
Ce-144			55.5(51.7)	0.13(0.12)
Eu-152				
Eu-155		0.18(0.12)		0.015(0.01)
Pb-210	0.725(0.721)			0.664(0.66)
Bi-207			0.55(0.45)	0.001(0.001)
Ra-226	0.36(0.04)	0.92(0.08)	1.95(1.0)	0.41(0.05)
Th-228	0.43(0.04)	0.97(0.09)	3.1(1.0)	0.48(0.05)
Th-232	0.37(0.09)	0.96(0.19)		0.42(0.1)
U-235	0.05(0.02)	0.15(0.06)	0.68(0.61)	0.06(0.02)
U-238		1.98(0.71)		0.16(0.06)
Am-241				

TABLE D.1. (contd.)

STATION: CC-3/1

Radionuclide Concentration - Bed Sediment
pCi/g

	Sand	Silt(a)	Clay	Composite
Sample Weight, Analysis (g)	80	Not available	8.8	
Sample Weight, Field (g)	883	437	9	1279
Be-7	5.13(3.58)			3.37(2.33)
K-40	9.93(1.67)		33.7(9.7)	6.7(1.16)
Mn-54				
Cr-51				
Co-60				
Zn-65				
Nb-95				
Ru-103				
Ru-106				
Rh-101			0.14(0.13)	0.001(0.001)
Rh-102				
Sb-125				
Cs-134	0.05(0.04)			0.03(0.03)
Cs-137	2.04(0.16)		21.8(1.5)	1.48(0.11)
Ce-141				
Ce-144				
Eu-152				
Eu-155				
Pb-210				
Bi-207				
Ra-226	0.44(0.06)		1.68(0.40)	0.30(0.04)
Th-228	0.44(0.07)		2.26(0.53)	0.30(0.05)
Th-232	0.43(0.18)			0.28(0.12)
U-235	0.07(0.04)		0.33(0.26)	0.07(0.03)
U-238	0.50(0.38)			0.33(0.25)
Am-241				

(a) Not analyzed

TABLE D.1. (contd.)

STATION: CC-3/2

Radionuclide Concentration - Bed Sediment
pCi/g

	Sand	Silt	Clay	Composite
Sample Weight, Analysis (g)	80	33.8	0.8	
Sample Weight, Field (g)	771.5	35.9	0.77	808.17
Be-7				
K-40	9.67(1.21)	10.9(2.5)		9.71(1.27)
Mn-54				
Cr-51				
Co-60				
Zn-65				0.013(0.01)
Nb-95				
Ru-103				
Ru-106				
Rh-101			1.12(0.83)	0.0011(0.0008)
Rh-102				
Sb-125			1.75(1.57)	0.0018(0.0016)
Cs-134	0.029(0.027)	0.12(0.06)	1.75(1.57)	0.035(0.03)
Cs-137	1.15(0.07)	2.11(0.21)	14.0(2.4)	1.21(0.08)
Ce-141				
Ce-144				
Eu-152				
Eu-155			5.62(3.99)	0.0056(0.004)
Pb-210				
Bi-207				
Ra-226	0.38(0.04)	0.89(0.11)	4.96(3.37)	0.41(0.05)
Th-228	0.43(0.05)	0.87(0.13)	5.33(3.02)	0.5(0.06)
Th-232	0.44(0.11)	1.04(0.30)		0.47(0.12)
U-235	0.10(0.03)	0.11(0.06)		0.10(0.03)
U-238	0.45(0.41)			0.43(0.39)
Am-241				

TABLE D.1. (contd.)

STATION: CC-3/3

Radionuclide Concentration - Bed Sediment
pCi/g

	Sand	Silt	Clay	Composite
Sample Weight, Analysis (g)	80	67.5	25	
Sample Weight, Field (g)	1554	292	28.2	1874.2
Be-7				
K-40	9.82(1.15)	13.4(2.17)	34.0(5.3)	10.74(1.37)
Mn-54	0.042(0.036)			0.035(0.03)
Cr-51				
Co-60		0.45(0.09)	1.59(0.27)	0.094(0.018)
Zn-65		0.29(0.22)		0.045(0.034)
Nb-95				
Ru-103				
Ru-106				
Rh-101				
Rh-102				
Sb-125				
Cs-134		0.61(0.07)	2.98(0.28)	0.14(0.015)
Cs-137	1.14(0.07)	27.6(0.50)	134.0(2.14)	7.26(0.17)
Ce-141				
Ce-144		0.51(0.42)		0.08(0.065)
Eu-152		0.13(0.09)		0.020(0.014)
Eu-155				
Pb-210				
Bi-207				
Ra-226	0.38(0.04)	1.05(0.11)	1.83(0.33)	0.51(0.06)
Th-228	0.42(0.05)	1.13(0.13)	2.4(0.4)	0.56(0.07)
Th-232	0.37(0.11)	0.71(0.36)	2.2(1.19)	0.45(0.17)
U-235	0.08(0.03)	0.19(0.08)	0.22(0.2)	0.10(0.04)
U-238	0.49(0.40)			0.41(0.33)
Am-241				

TABLE D.1. (contd.)

STATION: CC-5/1

Radionuclide Concentration - Bed Sediment
pCi/g

	Sand	Silt	Clay	Composite
Sample Weight, Analysis (g)	7.1(a)	50	22.5	
Sample Weight, Field (g)	3.61	364.5	40.5	408.61
Be-7				
K-40	7.29(4.42)	15.1(3.1)	37.5(5.8)	17.25(3.38)
Mn-54				
Cr-51				
Co-60				
Zn-65				
Nb-95				
Ru-103				
Ru-106				
Rh-101		0.05(0.04)	0.068(0.065)	0.051(0.0064)
Rh-102				
Sb-125	0.43(0.40)			0.004(0.004)
Cs-134				
Cs-137	1.16(0.25)	1.79(0.19)	5.4(0.42)	2.14(0.21)
Ce-141				
Ce-144			0.88(0.80)	0.09(0.007)
Eu-152				
Eu-155		0.2(0.19)		0.18(0.17)
Pb-210				
Bi-207				
Ra-226		1.03(0.12)	1.63(0.22)	1.08(0.13)
Th-228	0.63(0.25)	1.2(0.16)	2.15(0.28)	1.29(0.17)
Th-232		1.06(0.32)	2.32(0.64)	1.18(0.35)
U-235	0.18(0.14)	0.15(0.08)	0.45(0.16)	0.18(0.09)
U-238		1.93(1.06)	3.4(1.87)	2.06(1.13)
Am-241				

(a) Value of sample weight may have been read or recorded incorrectly.

TABLE D.1. (contd.)

STATION: CC-5/2

Radionuclide Concentration - Bed Sediment
pCi/g

	Sand(a)	Silt	Clay	Composite
Sample Weight, Analysis (g)	5.9	50	25	
Sample Weight, Field (g)	5.91	592	66	663.91
Be-7				
K-40	14.9(9.6)	14.6(2.7)	28.2(5.0)	15.9(3.0)
Mn-54			0.27(0.17)	0.03(0.02)
Co-57				
Co-60				
Zn-65				
Nb-95				
Ru-103				
Ru-106				
Rh-101				
Rh-102				
Sb-125				
Cs-134	0.35(0.17)			0.003(0.002)
Cs-137	1.5(0.32)	1.23(0.14)	3.35(0.37)	1.44(0.16)
Ce-141				
Ce-144				
Eu-152				
Eu-155				
Pb-210				
Bi-207				
Ra-226		0.99(0.1)	1.48(0.19)	1.03(0.11)
Th-228	1.13(0.44)	1.15(0.13)	1.99(0.25)	1.23(0.14)
Th-232	1.61(1.0)	1.06(0.31)	1.08(0.56)	1.07(0.34)
U-235	0.43(0.32)	0.17(0.06)	0.21(0.1)	0.18(0.07)
U-238				
Am-241				

TABLE D.1. (contd.)

STATION: CC-5/3

Radionuclide Concentration - Bed Sediment
pCi/g

	Sand(a)	Silt	Clay	Composite
Sample Weight, Analysis (g)	2.3	67.5	25	
Sample Weight, Field (g)	2.29	648	98	748.29
Be-7				
K-40		14.9(2.6)	25.7(4.7)	16.3(2.9)
Mn-54				
Cr-51				
Co-60			0.27(0.17)	0.04(0.02)
Zn-65				
Nb-95				
Ru-103				
Ru-106				
Rh-101			0.06(0.05)	0.008(0.007)
Rh-102				
Sb-125				
Cs-134			0.17(0.13)	0.022(0.017)
Cs-137	1.16(0.65)	1.14(0.14)	3.44(0.37)	1.44(0.17)
Ce-141				
Ce-144		0.56(0.39)	0.67(0.65)	0.57(0.42)
Eu-152	0.95(0.73)			0.003(0.002)
Eu-155		0.17(0.15)		0.15(0.13)
Pb-210				
Bi-207				
Ra-226	2.23(1.13)	1.03(0.1)	1.73(0.2)	1.13(0.12)
Th-228	1.87(1.1)	1.26(0.14)	2.1(0.27)	1.37(0.16)
Th-232	3.57(1.85)	0.69(0.28)	1.91(0.54)	0.86(0.32)
U-235	1.08(0.81)	0.17(0.66)	0.23(0.1)	0.18(0.59)
U-238		1.21(0.84)	3.06(1.16)	1.45(0.88)
Am-241				

TABLE D.1. (contd.)

STATION: CC-9

Radionuclide Concentration - Bed Sediment
pCi/g

	Sand	Silt	Clay	Composite
Sample Weight, Analysis (g)	80	67.5	2.5[(a)]	
Sample Weight, Field (g)	438.7	34.7	0.3	473.7
Be-7				
K-40	11.7(1.8)	12.8(2.1)	34.4(21.8)	11.80(1.84)
Mn-54				
Cr-51				
Co-60				
Zn-65				
Nb-95	0.29(0.29)			0.27(0.27)
Ru-103				
Ru-106				
Rh-101		0.032(0.02)	0.03(0.02)	0.0023(0.0015)
Rh-102				
Sb-125				
Cs-134				
Cs-137	0.34(0.06)	0.65(0.1)	3.37(0.72)	0.37(0.06)
Ce-141		2.86(2.54)		0.21(0.19)
Ce-144				
Eu-152				
Eu-155				
Pb-210				
Bi-207				
Ra-226	0.42(0.06)	0.89(0.08)	4.04(0.8)	0.46(0.06)
Th-228	0.36(0.08)	0.93(0.10)	3.07(0.97)	0.40(0.08)
Th-232	0.44(0.17)	0.79(0.23)	5.05(2.31)	0.47(0.18)
U-235		0.11(0.05)	0.99(0.75)	0.009(0.004)
U-238	1.01(0.55)	0.85(0.51)		1.0(0.55)
Am-241				

(a) Value of sample weight may have been read or recorded incorrectly.

TABLE D.1. (contd.)

STATION: CC-11

Radionuclide Concentration - Bed Sediment
pCi/g

	Sand	Silt	Clay	Composite
Sample Weight, Analysis (g)	40	67.5	22	
Sample Weight, Field (g)	52.49	502	44	598.49
Be-7	3.81(2.85)			0.34(0.26)
K-40	10.2(1.4)	12.8(2.1)	32.4(5.0)	13.9(2.2)
Mn-54			0.26(0.19)	0.02(0.02)
Co-57				
Co-60				
Zn-65				
Nb-95				
Ru-103				
Ru-106				
Rh-101		0.036(0.029)		0.03(0.024)
Rh-102				
Sb-125				
Cs-134				
Cs-137	0.23(0.05)	0.67(0.1)	3.29(0.3)	0.81(0.11)
Ce-141			12.9(9.44)	0.9(0.66)
Ce-144				
Eu-152				
Eu-155		0.13(0.1)	0.34(0.3)	0.13(0.11)
Pb-210			7.21(6.77)	0.50(0.47)
Bi-207	0.033(0.024)	0.05(0.004)		0.044(0.036)
Ra-226	0.38(0.05)	0.72(0.08)	1.51(0.19)	0.74(0.09)
Th-228	0.39(0.06)	1.06(0.01)	2.34(0.25)	1.09(0.11)
Th-232	0.4(0.13)	0.86(0.21)	2.33(0.52)	0.92(0.22)
U-235	0.08(0.03)	0.061(0.043)	0.27(0.13)	0.53(0.37)
U-238		1.15(0.49)	3.15(1.65)	1.19(0.53)
Am-241		0.18(0.12)		0.15(0.10)

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TABLE D.2. Concentrations of Radionuclides in Lake Erie Bed Sediment at the Mouth of Cattaraugus Creek. Results of gamma-ray measurements. Values in parentheses are two standard deviations of the propagated counting error.

STATION: Lake Erie

	Sample Weight, Analysis (g)	Radionuclide Concentration (pCi/g)									
		40K	137Cs	114Ce	155Eu	226Ra	228Th	232Th	235U	238U	Others
Sampling Point 1											
Top 2 inches	25.0	14.7 (3.3)	1.02 (0.19)			1.09 (0.15)	1.24 (0.19)	1.16 (0.39)	0.20 (0.06)		
2nd 2 inches	67.5	14.6 (2.2)	0.74 (0.10)			1.07 (0.09)	1.19 (0.12)	1.10 (0.23)	0.20 (0.06)	1.73 (0.70)	4.0(3.4) Pb-210
3rd 2 inches	67.5	11.4 (1.3)	0.33 (0.05)			0.60 (0.05)	0.65 (0.06)	0.55 (0.12)	0.09 (0.03)	0.96 (0.32)	0.19(0.018) Rh-101
Sampling Point 2											
Top 2 inches	64.1	14.1 (2.2)	0.57 (0.09)	0.70 (0.37)	0.16(0.14)	0.34 (0.09)	1.11 (0.12)	0.86 (0.24)	0.18 (0.06)	1.84 (0.77)	
2nd 2 inches	67.5	12.3 (2.0)	0.57 (0.09)	0.54 (0.38)		0.88 (0.08)	1.02 (0.10)	0.92 (0.22)	0.11 (0.04)	1.03 (0.49)	
3rd 2 inches	50.0	14.6 (2.6)	0.69 (0.11)			0.96 (0.10)	1.17 (0.13)	1.08 (0.29)	0.11 (0.06)	1.84 (0.82)	0.58(0.48) Nb-95, 0.05(0.033) Rh-101
Sampling Point 3											
Top 2 inches	50.0	14.2 (2.6)	0.72 (0.12)		0.19(0.16)	1.10 (0.10)	1.26 (0.13)	1.40 (0.27)	0.20 (0.06)	2.22 (0.82)	0.057(0.033) Rh-101
2nd 2 inches	67.5	16.9 (2.3)	0.67 (0.10		0.25 (0.14)	1.03 (0.05)	1.27 (0.12)	1.26 (0.24)	0.17 (0.06)	1.62 (0.74)	7.6(6.8) Ce-141
3rd 2 inches	64.9	12.3 (2.1)	0.49 (0.09)	0.5990.36)	0.13 (0.10)	0.90 (0.08)	1.04 (0.11)	0.71 (0.22)	0.14 (0.05)	1.64 (0.54)	0.048(0.034) Bi-207
Sampling Point 4											
Top 2 inches	67.5	11.2 (2.1)	0.58 (0.09)			0.66 (0.08)	0.67 (0.10)	0.61 (0.21)	0.11 (0.05)	0.88 (0.68)	0.42(0.36) Nb-95
2nd 2 inches	67.5	11.9 (2.0)	0.55 (0.10)			0.56 (0.07)	0.65 (0.09)	0.43 (0.20)			
3rd 2 inches	67.5	13.1 (2.1)	0.61 (0.10)			0.60 (0.07)	0.63 (0.09)	0.56 (0.19)	0.05 (0.04)	0.88 (0.42)	0.079(0.034) Cs-134

Note: Blanks indicate level was below detection
( ) parentheses represent two standard deviations

TABLE D.3. Concentration of Radionuclides in the Channel Bed Sediment of Buttermilk and Cattaraugus Creek Sampling Stations. Results of radiochemical analysis of alpha and beta emitter. Values in parentheses are one standard deviation of the propagated counting error.

STATION: Erdman's Brook

Radionuclide Concentration - Bed Sediment
pCi/g

	Sand	Silt	Clay	Composite
Sample Weight, Analysis (g)	67.5	50	25	
Sample Weight, Field (g)	443.5	532	83	1058.5
Sr-90	2.57 (0.17)	3.42 (0.21)	11.07 (0.65)	3.68 (0.23)
Pu-238	0.018 (0.002)	0.021 (0.002)	0.057 (0.006)	0.023 (0.002)
Pu-239,240	0.017 (0.002)	0.018 (0.002)	0.048 (0.005)	0.02 (0.002)
Am-241	0.025 (0.004)	0.029 (0.007)	0.072 (0.009)	0.031 (0.01)
Cm-244	<0.0001	0.01 (0.003)	0.011 (0.006)	0.0059 (0.002)

STATION: FC-1

Radionuclide Concentration - Bed Sediment
pCi/g

	Sand	Silt	Clay	Composite
Sample Weight, Analysis (g)	80	67.5	25.0	
Sample Weight, Field (g)	1207	531	53	1791
Sr-90	2.28 (0.16)	*	<0.0011	1.53 (0.1)
Pu-238	0.014 (0.003)	0.018 (0.001)	0.054 (0.006)	0.016 (0.003)
Pu-239,240	0.012 (0.003)	0.018 (0.002)	0.054 (0.006)	0.015 (0.003)
Am-241	0.019 (0.002)	0.054 (0.029)	0.047 (0.014)	0.03 (0.01)
Cm-244	<0.0001	<0.0001	0.028 (0.008)	0.00084 (0.0002)

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* Sample lost during analysis.

TABLE D.3. (contd.)

STATION: BC-4

Radionuclide Concentration - Bed Sediment
pCi/g

	Sand	Silt	Clay	Composite
Sample Weight, Analysis (g)	80	67.5	3.1	
Sample Weight, Field (g)	1627.5	287	15	1929.5
Sr-90	0.172 (0.033)	0.247 (0.128)	1.37 (0.623)	0.193 (0.05)
Pu-238	0.004 (0.002)	0.0076 (0.0006)	0.018 (0.003)	0.0046 (0.002)
Pu-239,240	0.004 (0.002)	0.0073 (0.0008)	0.020 (0.003)	0.0046 (0.002)
Am-241	0.009 (0.004)	<0.0014	<0.03	0.0076 (0.003)
Cm-244	<0.0001	0.0066 (0.0028)	0.012 (0.010)	0.0011 (0.0005)

STATION: CC-1

Radionuclide Concentration - Bed Sediment
pCi/g

	Sand	Silt	Clay	Composite
Sample Weight, Analysis (g)	80	33.8	1.8	
Sample Weight, Field (g)	665	59.8	1.75	726.55
Sr-90	<0.0001	<0.001	<0.2065	<0.00067
Pu-238	0.0004 (0.0003)	0.0007 (0.0002)	<0.003	0.0004 (0.0003)
Pu-239,240	0.0007 (0.0003)	0.0013 (0.0002)	0.1011 (0.006)	0.0008 (0.0003)
Am-241	<0.0012	<0.0028	0.065 (0.026)	0.0002 (0.0001)
Cm-244	<0.0001	<0.0002	0.015 (0.009)	0.00004 (0.00002)

TABLE D.3. (contd.)

STATION: CC-3/2

Radionuclide Concentration - Bed Sediment
pCi/g

	Sand	Silt	Clay	Composite
Sample Weight, Analysis (g)	80	33.8	0.8	
Sample Weight, Field (g)	771.5	35.9	0.77	808.1
Sr-90	<0.0001	0.078 (0.038)	<1.05	0.004 (0.002)
Pu-238	0.0004 (0.0001)	0.0008 (0.0001)	<0.0038	0.0004 (0.0001)
Pu-239,240	0.0008 (0.0002)	0.0009 (0.0003)	<0.017	0.0008 (0.0002)
Am-241	<0.0012	<0.0028	<0.1180	<0.0014
Cm-244	<0.0001	<0.0002	0.046 (0.021)	0.00004 (0.00002)

STATION: CC-5/2

Radionuclide Concentration - Bed Sediment
pCi/g

	Sand	Silt	Clay	Composite
Sample Weight, Analysis (g)	5.9	50	25	
Sample Weight, Field (g)	5.91	592	66	663.91
Sr-90	0.419 (0.335)	0.110 (0.059)	0.358 (0.081)	0.137 (0.063)
Pu-238	0.001 (0.001)	0.0009 (0.0003)	0.004 (0.001)	0.0012 (0.0003)
Pu-239,240	0.001 (0.001)	0.005 (0.001)	0.01 (0.001)	0.0055 (0.001)
Am-241	<0.016	0.024 (0.005)	<0.0038	0.021 (0.004)
Cm-244	<0.0013	0.005 (0.005)	<0.0003	0.0045 (0.0045)

TABLE D.3. (contd.)

STATION: CC-11

Radionuclide Concentration - Bed Sediment
pCi/g

	Sand	Silt	Clay	Composite
Sample Weight, Analysis (g)	40	67.5	22	
Sample Weight, Field (g)	52.49	502	44	598.49
Sr-90	<0.0004	0.047 (0.015)	0.178 (0.092)	0.052 (0.02)
Pu-238	<0.0001	0.0008 (0.0001)	0.0016 (0.0002)	0.00078 (0.000098)
Pu-239,240	0.0023 (0.0007)	0.0035 (0.0004)	0.0099 (0.0016)	0.0038 (0.00051)
Am-241	<0.0024	<0.0014	0.024 (0.006)	0.0017 (0.0004)
Cm-244	<0.0002	0.0077 (0.0023)	0.009 (0.006)	0.0006 (0.0004)

TABLE D.4. Concentration of Radionuclides in Lake Erie Bed Sediment at the Mouth of Cattaraugus Creek. Results of radiochemical analysis of alpha and beta emitting radionuclides. Values in parentheses are one standard deviation of the propagated counting error.

STATION: Lake Erie

Radionuclide Concentration (pCi/g)

Sampling Point	Sampling wt., Analysis (g)	Sr-90	Pu-238
1	25.0	0.220(0.130)	0.0018(0.0005)
2	64.1	0.573(0.047)	0.003(0.0013)
3	50.0	<0.00027	0.0004(0.0001)
4	67.5	(a)	<0.00004

Sampling Point	Pu-239,240	Am-241	Cm-244
1	0.0067(0.0016)	0.019(0.005)	0.039(0.008)
2	0.0047(0.0018)	0.011(0.003)	0.0062(0.0017)
3	0.005(0.0005)	<0.0019	0.017(0,004)
4	0.0033(0.0016	<0.0014	<0.0001

(a) Sample lost during analyis

TABLE D.5. Concentration of Radionuclides in the Suspended Sediment of Buttermilk and Cattaraugus Creek Sampling Stations. Results of gamma-ray measurements. Values in parentheses are two standard deviations of the propagated counting error.

STATION: GVC

Radionuclide Concentration - Suspended Sediment
pCi/g

	Clay	Silt	Composite
Sample Weight, Analyses (g)	2.5	4.6	
Sample Weight, Field (g)	2.562	4.582	7.1440
Be-7			
K-40	41.5 (14.6)	21.9 (12.3)	28.9 (13.13)
Cr-51			
Mn-54			
Co-60			
Zn-65			
Nb-95			
Rh-101			
Rh-102			
Sb-125	1.15 (1.13)	0.37 (0.31)	0.24 (0.20)
Cs-134		0.42 (0.31)	0.27 (0.20)
Cs-137	2.57 (0.73)	0.89 (0.39)	1.49 (0.51)
Ce-141			
Ce-144		3.57 (1.93)	2.29 (1.24)
Eu-155		0.96 (0.76)	0.62 (0.49)
Pb-210			
Bi-207			
Ra-226		1.68 (0.51)	1.08 (0.33)
Th-228	1.24 (0.76)	1.89 (0.55)	1.66 (0.53)
Th-232		3.95 (1.17)	2.53 (0.75)
U-235			
U-238		4.76 (4.65)	3.05 (2.98)
Am-241			

TABLE D.5. (contd.)

STATION: BC-1

Radionuclide Concentration - Suspended Sediment
pCi/g

	Clay	Silt	Composite
Sample Weight, Analyses (g)	2.3	10.7	
Sample Weight, Field (g)	2.283	10.87	13.1530
Be-7			
K-40	39.9 (9.1)	14.7 (4.1)	19.1 (5.0)
Cr-51			
Mn-54	0.53 (0.37)		0.44 (0.31)
Co-60			
Zn-65			
Nb-95			
Rh-101			
Rh-102			
Sb-125			
Cs-134			
Cs-137	0.66 (0.31)	0.13 (0.13)	0.22 (0.16)
Ce-141			
Ce-144		1.01 (0.86)	0.83 (0.714)
Eu-155			
Pb-210	9.67 (8.04)		1.68 (1.40)
Bi-207		0.96 (0.092)	0.079(0.075)
Ra-226	1.73 (0.38)	0.93 (0.17)	1.07 (0.21)
Th-228	2.40 (0.47)	1.32 (0.22)	1.51 (0.26)
Th-232	2.63 (1.16)	1.42 (0.56)	1.63 (0.66)
U-235		0.11 (0.11)	0.09 (0.09)
U-238	4.19 (2.30)		0.73 (0.4)
Am-241			

TABLE D.5. (contd.)

STATION: FC-1

Radionuclide Concentration – Suspended Sediment
pCi/g

	Clay	Silt	Composite
Sample Weight, Analyses (g)	3.4	8.5	
Sample Weight, Field (g)	3.432	8.744	12.1760
Be-7			
K-40	27.4 (17.1)	21.9 (5.0)	23.44 (8.39)
Mn-54			
Co-60			
Zn-65			
Nb-95	3.30 (3.11)		0.92 (0.87)
Rh-101			
Rh-102			
Sb-125		0.25 (0.16)	0.18 (0.12)
Cs-134		0.34 (0.13)	0.245 (0.09)
Cs-137	32.5 (1.5)	11.7 (0.6)	17.52 (0.85)
Ce-141			
Ce-144			
Eu-155			
Pb-210			
Bi-207			
Ra-226		0.80 (0.21)	0.58 (0.15)
Th-228	2.54 (0.75)	0.98 (0.25)	1.42 (0.39)
Th-232		1.31 (0.73)	0.94 (0.53)
U-235	0.65 (0.57)		0.18 (0.16)
U-238			
Am-241			

TABLE D.5. (contd.)

STATION: BC-1

Radionuclide Concentration - Suspended Sediment
pCi/g

	Clay[(a)]	Silt	Composite
Sample Weight, Analysis (gms)	17.8	25.0	
Sample Weight, Field (gms)	17.680	59.562	77.2422
Be-7			
K-40		20.0 (2.6)	15.4 (2.0)
Cr-51			
Mn-54			
Co-60			
Zn-65			
Nb-95			
Rh-101			
Rh-102			
Sb-125			
Cs-134			
Cs-137			
Ce-141			
Ce-144			
Eu-155			
Pb-210			
Bi-207			
Ra-226		1.06 (0.10)	0.82 (0.08)
Th-228		1.35 (0.13)	1.04 (0.10)
Th-232		1.03 (0.26)	0.79 (0.20)
U-235		0.14 (0.08)	0.11 (0.06)
U-238		2.35 (0.96)	1.81 (0.74)
Am-241			

(a) Clay sizes not analyzed

TABLE D.5. (contd.)

STATION: CC-1

Radionuclide Concentration - Suspended Sediment
pCi/g (dry wt)

	Clay	Silt	Composite
Sample Weight, Analyses (g)	3.5	11.1	
Sample Weight, Field (g)	3.433	13.997	17.43
Be-7			
K-40	32.4 (10.9)	17.5 (5.0)	20.4 (6.2)
Cr-51			
Mn-54			
Co-60			
Zn-65	1.73 (1.41)		0.34 (0.28)
Nb-95			
Rh-101		0.09 (0.04)	0.07 (0.03)
Rh-102			
Sb-125			
Cs-134			
Cs-137	1.10 (0.41)	0.35 (0.19)	0.50 (0.23)
Ce-141		18.8 (13.3)	15.1 (10.7)
Ce-144			
Eu-155	0.69 (0.62)		0.14 (0.12)
Pb-210			
Bi-207			
Ra-226	1.16 (0.47)	0.77 (0.19)	0.85 (0.25)
Th-228	1.54 (0.53)	1.18 (0.24)	1.25 (0.30)
Th-232		1.11 (0.57)	0.89 (0.46)
U-235		0.19 (0.12)	0.15 (0.10)
U-238			
Am-241		0.39 (0.19)	0.31 (0.15)

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TABLE D.5. (contd.)

STATION: CC-3/1 Top

Radionuclide Concentration - Suspended Sediment
pCi/g (dry wt)

	Clay	Silt	Composite
Sample Weight, Analyses (g)	1.7	6.9	
Sample Weight, Field (g)	1.803	6.924	8.7270
Be-7			
K-40	39.9 (32.7)		8.38 (6.87)
Mn-54			
Cr-51			
Co-60	1.13 (1.03)		8.24 (0.22)
Zn-65			
Nb-95			
Rh-101			
Rh-102			
Sb-125			
Cs-134	0.84 (0.71)		0.18 (0.15)
Cs-137	2.8 (0.98)	1.16 (0.30)	1.50 (0.44)
Ce-141			
Ce-144			
Eu-155			
Pb-210			
Bi-207			
Ra-226		1.23 (0.30)	0.97 (0.24)
Th-228	3.47 (1.38)	1.25 (0.39)	1.72 (0.60)
Th-232	3.34 (3.26)	1.45 (0.92)	1.85 (1.41)
U-235		0.39 (0.28)	0.31 (0.22)
U-238			
Am-241			

TABLE D.5. (contd.)

STATION: CC-3/1 Bottom

Radionuclide Concentration - Suspended Sediment
pCi/g

	Clay	Silt	Composite
Sample Weight, Analyses (g)	4.5	10.0	
Sample Weight, Field (g)	4.466	10.148	14.6140
Be-7			
K-40	36.7 (13.4)	25.7 (7.2)	29.11 (9.1)
Cr-51			
Mn-54			
Co-60			
Zn-65			
Nb-95			
Rh-101			
Rh-102			
Sb-125			
Cs-134		0.3 (0.21)	0.21 (0.14)
Cs-137	2.88 (0.5)	1.76 (0.38)	2.11 (0.42)
Ce-141			
Ce-144			
Eu-155			
Pb-210			
Bi-207		0.19 (0.15)	0.13 (0.10)
Ra-226	1.15 (0.5)	0.76 (0.24)	0.88 (0.32)
Th-228	1.82 (0.57)	1.42 (0.35)	1.54 (0.42)
Th-232		1.75 (0.84)	1.21 (0.58)
U-235	0.49 (0.42)		0.15 (0.13)
U-238			
Am-241			

TABLE D.5. (contd.)

STATION: CC-3/2

Radionuclide Concentration - Suspended Sediment
pCi/g

	Clay	Silt	Composite
Sample Weight, Analyses (g)	5.6	19.1	
Sample Weight, Field (g)	5.545	19.309	24.854
Be-7			
K-40	33.8 (10.6)	24.5 (5.3)	26.55 (6.47)
Cr-51	293.0 (290.0)		64.5 (63.8)
Mn-54			
Co-60			
Zn-65	0.171 (1.05)		0.04 (0.23)
Nb-95			
Rh-101			
Rh-102			
Sb-125			
Cs-134			
Cs-137	4.29 (0.45)	1.17 (0.27)	1.86 (0.31)
Ce-141			
Ce-144			
Eu-155		0.359 (0.323)	0.28 (0.25)
Pb-210			
Bi-207		0.162 (0.099)	0.13 (0.08)
Ra-226	1.03 (0.34)	1.11 (0.20)	1.09 (0.23)
Th-228	1.86 (0.45)	1.8 (0.27)	1.81 (0.31)
Th-232	2.62 (1.02)		0.58 (0.22)
U-235		0.26 (0.15)	0.20 (0.12)
U-238		1.95 (1.79)	1.52 (1.4)
Am-241			

TABLE D.5. (contd.)

STATION: CC-3/3

Radionuclide Concentration - Suspended Sediment
pCi/g

	Clay	Silt	Composite
Sample Weight, Analyses (g)	2.1	15.1	
Sample Weight, Field (g)	2.104	15.27	17.374
Be-7			
K-40	31.8 (15.8)	20.3 (3.4)	21.68 (4.9)
Cr-51			
Mn-54			
Co-60			
Zn-65			
Nb-95			
Rh-101			
Rh-102			
Sb-125			
Cs-134			
Cs-137	5.0 (0.95)	1.72 (0.20)	2.11 (0.29)
Ce-141			
Ce-144			
Eu-155			
Pb-210			
Bi-207			
Ra-226		0.77 (0.13)	0.68 (0.11)
Th-228	2.42 (0.89)	0.98 (0.16)	1.15 (0.25)
Th-232		0.92 (0.34)	0.81 (0.30)
U-235		0.13 (0.08)	0.11 (0.07)
U-238			
Am-241			

[redacted]

TABLE D.5. (contd.)

STATION: CC-5/1

Radionuclide Concentration - Suspended Sediment
pCi/g

	Clay	Silt	Composite
Sample Weight, Analyses (g)	4.2	25.0	
Sample Weight, Field (g)	4.142	34.445	38.5870
Be-7		6.23 (3.89)	
K-40	30.9 (13.7)	19.5 (2.4)	20.8 (3.6)
Cr-51			
Mn-54			
Co-60			
Zn-65			
Nb-95			
Rh-101		0.026 (0.025)	0.023 (0.022)
Rh-102			
Sb-125			
Cs-134			
Cs-137	1.90 (0.45)	1.17 (0.13)	1.25 (0.17)
Ce-144			
Eu-155		0.14 (0.11)	0.12 (0.10)
Pb-210			
Bi-207	0.29 (0.25)		0.032 (0.028)
Ra-226	1.22 (0.46)	0.96 (0.09)	0.98 (0.16)
Th-228	1.98 (0.60)	1.38 (0.12)	1.45 (0.17)
Th-232		0.95 (0.27)	0.85 (0.24)
U-235	0.46 (0.45)	0.15 (0.05)	0.18 (0.09)
U-238		1.15 (0.58)	1.02 (0.52)
Am-241			

TABLE D.5. (contd.)

STATION: CC-5/2 Top

Radionuclide Concentration - Suspended Sediment
pCi/g

	Clay	Silt	Composite
Sample Weight, Analyses (g)	3.2	16.0	
Sample Weight, Field (g)	3.194	15.99	19.184
Be-7			
K-40	37.5 (11.3)	19.3 (4.8)	22.4 (5.9)
Cr-51			
Mn-54			
Co-60			
Zn-65			
Nb-95			
Rh-101		0.06 (0.05)	0.05 (0.04)
Rh-102			
Sb-125			
Cs-134			
Cs-137	2.09 (0.57)	1.01 (0.23)	1.19 (0.29)
Ce-141			
Ce-144			
Eu-155			
Pb-210			
Bi-207			
Ra-226	1.0 (0.72)	0.85 (0.17)	0.88 (0.26)
Th-228	2.38 (0.6)	1.33 (0.23)	1.51 (0.29)
Th-232		0.79 (0.53)	0.66 (0.44)
U-235		0.17 (0.11)	0.14 (0.09)
U-238			
Am-241			

[redacted]

TABLE D.5. (contd.)

STATION: CC-5/2 Mid-depth

Radionuclide Concentration - Suspended Sediment
pCi/g

	Clay	Silt	Composite
Sample Weight, Analyses (g)	4.1	25.0	
Sample Weight, Field (g)	4.043	27.781	31.824
Be-7			
K-40	32.9 (14.2)	21.1 (3.0)	22.6 (4.5)
Cr-51	765.0 (632.0)		99.4 (81.0)
Mn-54			
Co-60			
Zn-65			
Nb-95			
Rh-101			
Rh-102			
Sb-125	1.39 (0.88)		0.18 (0.11)
Cs-134			
Cs-137	2.15 (0.49)	1.15 (0.14)	1.28 (0.19)
Ce-144			
Eu-155	0.91 (0.88)		0.12 (0.11)
Pb-210			
Bi-207			
Ra-226	1.57 (0.48)	1.15 (0.12)	1.20 (0.17)
Th-228	1.82 (0.62)	1.46 (0.15)	1.51 (0.21)
Th-232	1.61 (1.47)	1.36 (0.31)	1.39 (0.46)
U-235		0.22 (0.09)	0.19 (0.08)
U-238		1.72 (1.09)	1.50 (0.95)
Am-241			

TABLE D.5. (contd.)

STATION: CC-5/2 Bottom

Radionuclide Concentration - Suspended Sediment
pCi/g

	Clay	Silt	Composite
Sample Weight, Analyses (g)	4.8	25.0	
Sample Weight, Field (g)	4.827	44.401	49.2280
Be-7			
K-40	40.0 (8.6)	19.0 (2.8)	21.10 (3.38)
Cr-51			
Mn-54			
Co-60			
Zn-65			
Nb-95			
Rh-101			
Rh-102		0.086 (0.054)	0.08 (0.05)
Sb-125			
Cs-134			
Cs-137	2.07 (0.41)	1.11 (0.15)	1.21 (0.18)
Ce-141	25.5 (21.0)		2.55 (2.10)
Ce-144			
Eu-155		0.14 (0.12)	0.13 (0.11)
Pb-210			
Bi-207			
Ra-226	1.14 (0.36)	0.92 (0.11)	0.94 (0.14)
Th-228	1.92 (0.42)	1.35 (0.14)	1.41 (0.17)
Th-232	1.96 (1.01)	1.13 (0.32)	1.21 (0.39)
U-235	0.30 (0.21)	0.13 (0.06)	0.15 (0.08)
U-238	4.37 (2.23)		0.44 (0.22)
Am-241			

TABLE D.5. (contd.)

STATION: CC-5/3

Radionuclide Concentration - Suspended Sediment
pCi/g (dry wt)

	Clay	Silt	Composite
Sample Weight, Analyses (g)	2.1	20.7	
Sample Weight, Field (g)	2.119	20.708	22.827
Be-7	84.5 (67.6)		7.86 (6.28)
K-40	31.1 (14.6))	17.4 (3.9)	18.67 (4.90)
Cr-51			
Mn-54			
Co-60			
Zn-65			
Nb-95			
Rh-101			
Rh-102	0.51 (0.45)		0.05 (0.04)
Sb-125			
Cs-134			
Cs-137	2.36 (0.69)	1.20 (0.23)	1.31 (0.27)
Ce-141			
Ce-144			
Eu-155			
Pb-210			
Bi-207			
Ra-226		1.00 (0.17)	0.91 (0.15)
Th-228	2.43 (0.84)	1.15 (0.22)	1.27 (0.28)
Th-232		1.04 (0.52)	0.94 (0.47)
U-235		0.15 (0.09)	0.14 (0.08)
U-238			
Am-241			

[redacted]

TABLE D.5. (contd.)

STATION: CC-9

Radionuclide Concentration - Suspended Sediment
pCi/g

	Clay	Silt	Composite
Sample Weight, Analyses (g)	8.3	24.5	
Sample Weight, Field (g)	8.277	24.308	32.5850
Be-7			
K-40	27.0 (5.6)	25.7 (4.3)	26.0 (4.6)
Cr-51	343.0 (231.0)		85.8 (57.8)
Mn-54		0.17 (0.15)	0.13 (0.11)
Co-60			
Zn-65			
Nb-95			
Rh-101		0.07 (0.05)	0.05 (0.04)
Rh-102			
Sb-125			
Cs-134			
Cs-137	2.74 (0.34)	1.85 (0.22)	2.07 (0.25)
Ce-141		13.1 (9.15)	9.83 (6.86)
Ce-144			
Eu-155			
Pb-210			
Bi-207			
Ra-226	1.11 (0.21)	0.87 (0.15)	0.93 (0.17)
Th-228	1.61 (0.28)	1.48 (0.21)	1.51 (0.23)
Th-232	1.37 (0.59)	1.43 (0.49)	1.42 (0.52)
U-235	0.25 (0.14)	0.21 (0.12)	0.22 (0.13)
U-238		2.12 (1.41)	1.59 (1.06)
Am-241			

TABLE D.5. (contd.)

STATION: CC-11 Top

Radionuclide Concentration - Suspended Sediment
pCi/g

	Clay	Silt	Composite
Sample Weight, Analyses (g)	3.1	13.0	
Sample Weight, Field (g)	3.041	12.869	15.91
Be-7			
K-40	33.8 (11.9)	19.0 (3.6)	21.8 (5.2)
Cr-51			
Mn-54			
Co-60			
Zn-65			
Nb-95			
Rh-101			
Rh-102	0.49 (0.35)		0.09 (0.07)
Sb-125			
Cs-134			
Cs-137	2.51 (0.59)	1.41 (0.20)	1.62 (0.27)
Ce-141			
Ce-144			
Eu-155			
Pb-210			
Bi-207			
Ra-226	1.46 (0.72)	1.1 (0.14)	1.17 (0.25)
Th-228	2.01 (0.63)	0.98 (0.18)	1.18 (0.27)
Th-232	1.8 (1.66)	1.2 (0.44)	1.31 (0.67)
U-235		0.18 (0.09)	0.15 (0.07)
U-238			
Am-241			

TABLE D.5. (contd.)

STATION: CC-11 Bottom

Radionuclide Concentration - Suspended Sediment
pCi/g

	Clay	Silt	Composite
Sample Weight, Analyses (g)	3.2	20.4	
Sample Weight, Field (g)	3.213	20.456	23.669
Be-7			
K-40	21.1 (16.8)	19.2 (3.1)	19.47 (5.0)
Cr-51			
Mn-54			
Co-60			
Nb-95			
Zn-65			
Rh-101			
Rh-102			
Sb-125			
Cs-134			
Cs-137	2.71 (0.57)	1.82 (0.20)	1.94 (0.25)
Ce-141	43.8 (29.4)		6.13 (4.12)
Ce-144			
Eu-155		0.22 (0.14)	0.19 (0.12)
Pb-210			
Bi-207			
Ra-226		1.02 (0.13)	0.88 (0.11)
Th-228	2.54 (0.8)	1.44 (0.17)	1.57 (0.26)
Th-232	2.77 (1.56)	1.36 (0.36)	1.56 (0.53)
U-235		0.17 (0.08)	0.15 (0.07)
U-238		1.0 (0.72)	0.86 (0.62)
Am-241			

TABLE D.6. Radionuclide Concentration in the Suspended Sediment of Buttermilk and Cattaraugus Creek Sampling Stations. Results of radiochemical analysis of alpha and beta emitting radionuclides. Values in parentheses are one standard deviation of the propagated counting error.

STATION: GVC

Radionuclide Concentration - Suspended Sediment
pCi/g

	Clay	Silt	Composite
Sample Weight, Analyses (g)	2.5	4.6	
Sample Weight, Field (g)	2.562	4.582	7.144
Sr-90	84.04 (4.84)	<0.0316	30.17 (1.74)
Pu-238	<0.0012	<0.0007	0
Pu-239,240	0.006 (0.003)	0.012 (0.002)	0.0098 (0.0024)
Am-241	<0.0014	0.698 (0.073)	0.447 (0.047)
Cm-244	0.014 (0.014)	0.075 (0.020)	0.053 (0.018)

STATION: FC-1

Radionuclide Concentration - Suspended Sediment
pCi/g

	Clay	Silt	Composite
Sample Weight, Analyses (g)	3.4	8.5	
Sample Weight, Field (g)	3.432	8.744	12.176
Sr-90	6.00 (0.65)	4.68 (0.48)	5.05 (0.53)
Pu-238	<0.0009	0.0096 (0.0029)	0.0069 (0.001)
Pu-239,240	0.027 (0.007)	0.0072 (0.0026)	0.0128 (0.0038)
Am-241	0.437 (0.057)	0.073 (0.015)	0.176 (0.027)
Cm-244	0.057 (0.018)	<0.0009	0.016 (0.005)

TABLE D.6. (contd.)

STATION: BC-4

Radionuclide Concentration - Suspended Sediment
pCi/g

	Clay	Silt	Composite
Sample Weight, Analyses (g)	17.8	25.0	
Sample Weight, Field (g)	17.68	59.562	77.242
Sr-90	0.327 (0.059)	*	0.075 (0.14)
Pu-238	0.004 (0.001)	0.0014 (0.0004)	0.0028 (0.0005)
Pu-239,240	0.003 (0.001)	0.0026 (0.0005)	0.0027 (0.0006)
Am-241	0.118 (0.021)	0.006 (0.004)	0.032 (0.0079)
Cm-244	0.067 (0.014)	<0.0003	0.015 (0.003)

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* Sample lost during analysis.

STATION: CC-1

Radionuclide Concentration - Suspended Sediment
pCi/g

	Clay	Silt	Composite
Sample Weight, Analyses (g)	3.5	14.1	
Sample Weight, Field (g)	3.433	13.997	17.43
Sr-90	778.85 (43.24)	<0.0034	153.43 (8.52)
Pu-238	0.002 (0.002)	<0.0002	0.0004 (0.0004)
Pu-239,240	<0.004	0.0009 (0.0007)	0.0007 (0.0006)
Am-241	0.622 (0.067)	0.244 (0.021)	0.318 (0.03)
Cm-244	0.051 (0.016)	0.023 (0.006)	0.028 (0.008)

TABLE D.6. (contd.)

STATION: CC-3/2

Radionuclide Concentration - Suspended Sediment
pCi/g

	Clay	Silt	Composite
Sample Weight, Analyses (g)	5.6	14.1	
Sample Weight, Field (g)	5.545	19.309	24.85
Sr-90	0.359 (0.179)	<0.00104	0.079 (0.039)
Pu-238	<0.0005	0.0039 (0.0001)	0.003 (0.00008)
Pu-239,240	<0.0025	0.0027 (0.0009)	0.002 (0.0007)
Am-241	<0.0170	<0.0067	<0.009
Cm-244	<0.0014	<0.0005	<0.0007

STATION: CC-5/2 Mid-depth

Radionuclide Concentration - Suspended Sediment
pCi/g

	Clay	Silt	Composite
Sample Weight, Analyses (g)	4.1	25.0	
Sample Weight, Field (g)	4.043	27.781	31.824
Sr-90	<0.0398	0.192 (0.144)	0.167 (0.125)
Pu-238	<0.0007	0.0006 (0.0001)	0.00052 (0.00009)
Pu-239,240	<0.0034	0.0027 (0.0006)	0.0024 (0.0005)
Am-241	0.099 (0.018)	0.021 (0.006)	0.031 (0.0007)
Cm-244	<0.0019	0.0089 (0.0035)	0.0077 (0.0031)

TABLE D.6. (contd.)

STATION: CC-11 Bottom

Radionuclide Concentration - Suspended Sediment
pCi/g

	Clay	Silt	Composite
Sample Weight, Analyses (g)	3.2	20.4	
Sample Weight, Field (g)	3.213	20.456	23.669
Sr-90	<0.0653	0.185 (0.078)	0.159 (0.067)
Pu-238	0.004 (0.002)	0.002 (0.0005)	0.0023 (0.0007)
Pu-239,240	<0.0044	0.005 (0.001)	0.0043 (0.00086)
Am-241	0.109 (0.030)	0.013 (0.012)	0.0026 (0.015)
Cm-244	<0.0024	<0.0004	<0.0007

TABLE D.7. Concentration of Radionuclides in the Water of Buttermilk and Cattaraugus Creek Sampling Stations. Results of gamma-ray measurements. Values in parentheses are one standard deviation of propagated counting error except for stations FC-1, BC-4, CC-1, and CC-11 (top) where the error is two standard deviations.

STATION: GVC (BACKGROUND)

Isotope	Particulate Filters pCi/liter	Dissolved pCi/liter: Aluminum Oxide Beds 1st	Aluminum Oxide Beds 2nd	Resin Beds 1st	Resin Beds 2nd	Total Dissolved pCi/liter	Total Dissolved and Particulate pCi/liter
Sample Wt (g)	10	368	390	155	155		
K-40	0.14 (0.08)	<0.51	<0.30	<0.18	<0.18	<1.17	0.14 (0.08)
Co-60	<0.01	<0.03	<0.02	<0.04	<0.04	<0.13	<0.14
Cs-134	<0.02	<0.04	<0.02	<0.04	<0.04	<0.14	<0.16
Cs-137	<0.01	<0.03	<0.01	<0.04	<0.02	<0.10	<0.11
Ce-144	<0.14	<0.33	<0.20	<0.37	<0.37	<1.27	<1.41
Bi-207	<0.01	<0.02	<0.01	<0.02	<0.02	<0.07	<0.08
Ra-226	<0.02	<0.05	<0.03	<0.06	<0.06	<0.20	<0.22
Ra-228	0.03 (0.02)	<0.14	<0.10	<0.16	<0.16	<0.56	0.03 (0.02)
Th-228	<0.02	<0.09	<0.04	<0.06	<0.06	<0.25	<0.27
U-235	<0.05	<0.14	<0.10	<0.16	<0.16	<0.56	<0.61
U-238	<0.12	<0.37	<0.40	<0.31	<0.31	<1.39	<1.51
Am-241	0.10 (0.01)	0.42 (0.03)	0.15 (0.01)	<0.06	<0.08	0.57*	0.67*

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* Indicates standard deviation cannot be determined.

TABLE D.7. (contd.)

STATION: BC-1

Isotope	Particulate Filters pCi/liter	Dissolved pCi/liter				Total Dissolved pCi/liter	Total Dissolved and Particulate pCi/liter
		Aluminum Oxide Beds		Resin Beds			
		1st	2nd	1st	2nd		
Sample Wt (g)	19	432	441	183	162		
K-40	0.57 (0.04)	<0.11	<0.08	1.15 (0.79)	0.51 (0.14)	1.66*	2.23*
Co-60	<0.01	<0.25	<0.05	<0.10	<0.02	<0.42	<0.43
Cs-134	<0.01	<0.25	<0.06	<0.10	<0.02	<0.43	<0.44
Cs-137	<0.005	<0.25	<0.04	<0.05	<0.01	<0.35	<0.355
Ce-144	<0.07	<2.35	<0.51	<0.10	<0.19	<3.15	<3.22
Bi-207	<0.004	<0.12	<0.04	<0.05	<0.01	<0.22	<0.224
Ra-226	<0.01	<0.37	<0.09	<0.16	<0.03	<0.65	<0.66
Ra-228	<0.03	<0.99	<0.25	<0.42	<0.09	<1.75	<1.78
Th-228	0.03 (0.005)	<0.50	<0.13	<0.21	<0.05	<0.89	0.03 (0.005)
U-235	<0.03	<0.99	<0.25	<0.42	<0.09	<1.75	<1.78
U-238	<0.07	<1.98	<0.63	<0.84	<0.23	<3.68	<3.75
Am-241	1.12 (0.01)	1.11 (0.12)	0.25 (0.03)	<0.16	<0.04	1.36*	2.48*

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* Indicates standard deviation cannot be determined.

TABLE D.7. (contd.)

STATION: FC-1

Isotope	Particulate Filters pCi/liter	Dissolved pCi/liter Aluminum Oxide Beds 1st	2nd	3rd	Resin Beds 1st	2nd	3rd	Total Dissolved pCi/liter	Total Dissolved and Particulate pCi/liter
Be-7		13.3 (9.5)						13.3 (9.5)	13.3 (9.5)
K-40	1.4 (0.52)				3.1 (2.1)			3.1 (2.1)	4.5*
Mn-54									
Co-60									
Nb-95					0.34 (0.27)			0.34 (0.27)	0.34 (0.27)
Rh-102		0.19 (0.13)			0.049 (0.046)			0.24*	0.24*
Sb-125		0.86 (0.35)						0.86 (0.35)	0.86 (0.35)
Cs-134									
Cs-137	0.08 (0.02)	0.16 (0.15)			0.31 (0.07)			0.47*	0.55*
Ce-141				7.2 (5.9)				7.2 (5.9)	7.2 (5.9)
Ce-144									
Eu-155									
Pb-210									
Ra-226									
Th-228									
Th-232	0.08 (0.07)		0.67 (0.63)		0.23 (0.22)	0.51 (0.26)		1.41*	1.49*
U-235									
U-238									
Am-241									

Blanks indicate activity levels below detection.
* Indicates standard deviation cannot be determined.

TABLE D.7. (contd.)

STATION: BC-4

Isotope	Particulate Filters pCi/liter	Dissolved pCi/liter Aluminum Oxide Beds			Resin Beds			Total Dissolved pCi/liter	Total Dissolved and Particulate pCi/liter
		1st	2nd	3rd	1st	2nd	3rd		
Be-7					0.58 (0.46)			0.58 (0.46)	0.58 (0.46)
K-40	0.21 (0.07)					0.24 (0.13)	0.50 (0.18)	0.74*	0.95*
Mn-54				0.021 (0.019)	0.013 (0.010)			0.034*	0.034*
Co-60							0.009 (0.008)	0.009 (0.008)	0.009 (0.008)
Nb-95									
Rh-102									
Sb-125		0.05 (0.04)						0.05 (0.04)	0.05 (0.04)
Cs-134									
Cs-137	0.02 (0.003)						0.008 (0.006)	0.008 (0.006)	0.028*
Ce-141	0.09 (0.07)								0.09 (0.07)
Ce-144									
Eu-155					0.02 (0.01)			0.02 (0.01)	0.02 (0.01)
Pb-210									
Ra-226									
Th-228	0.006 (0.003)				0.014 (0.011)			0.014 (0.011)	0.020*
Th-232						0.03 (0.02)	0.03 (0.02)	0.06*	0.06*
U-235									
U-238		0.31 (0.28)		0.39 (0.25)				0.70*	0.70*
Am-241	0.02 (0.005)								0.02 (0.005)

Blanks indicate activity levels below detection.
* Indicates standard deviation cannot be determined.

TABLE D.7. (contd.)

STATION: CC-1

Isotope	Particulate Filters pCi/liter	Dissolved pCi/liter						Total Dissolved pCi/liter	Total Dissolved and Particulate pCi/liter
		Aluminum Oxide Beds			Resin Beds				
		1st	2nd	3rd	1st	2nd	3rd		
Be-7									
K-40	0.20 (0.07)					0.48 (0.44)	0.87 (0.37)	1.35*	1.55*
Mn-54									
Co-60		0.04 (0.03)						0.04 (0.03)	0.04 (0.03)
Nb-95									
Rh-102									
Sb-125									
Cs-134									
Cs-137									
Ce-141									
Ce-144									
Eu-155				0.034 (0.028)				0.034 (0.028)	0.034 (0.028)
Pb-210					0.41 (0.40)			0.41 (0.40)	0.41 (0.40)
Ra-226									
Th-228	0.006 (0.003)								0.006 (0.003)
Th-232				0.08 (0.07)				0.08 (0.07)	0.08 (0.07)
U-235									
U-238			0.18 (0.15)			0.24 (0.19)		0.42*	0.42*
Am-241	0.93 (0.02)	0.90 (0.10)	0.10 (0.04)	0.12 (0.04)			0.04 (0.03)	1.16*	2.09*

Blanks indicate activity levels below detection.
* Indicates standard deviation cannot be determined.

TABLE D.7. (contd.)

STATION: CC-3/1 (Top)

Isotope	Particulate Filters pCi/liter	Dissolved pCi/liter Aluminum Oxide Beds 1st	 2nd	 Resin Beds 1st	 2nd	Total Dissolved pCi/liter	Total Dissolved and Particulate pCi/liter
Sample Wt (g)	16	449	444	199	198		
K-40	0.19 (0.02)	0.11 (0.11)	<0.50	0.37 (0.15)	0.71 (0.30)	1.69*	1.88*
Co-60	<0.002	<0.02	<0.11	<0.02	<0.05	<0.20	<0.202
Cs-134	<0.004	<0.03	<0.17	<0.02	<0.07	<0.29	<0.294
Cs-137	<0.002	<0.02	<0.11	<0.02	<0.05	<0.20	<0.202
Ce-144	<0.03	<0.28	<1.27	<0.27	<0.54	<2.36	<2.39
Bi-207	<0.002	<0.02	<0.06	<0.02	<0.02	<0.12	<0.122
Ra-226	<0.004	<0.04	<0.17	<0.02	<0.07	<0.30	<0.304
Ra-228	<0.01	<0.11	<0.50	<0.10	<0.07	<0.78	<0.79
Th-228	0.01 (0.002)	0.04 (0.02)	<0.04	<0.05	<0.10	0.04 (0.02)	0.05*
U-235	<0.01	<0.11	<0.50	<0.10	<0.22	<0.93	<0.94
U-238	<0.03	<0.28	<1.00	<0.30	<0.44	<2.02	<2.05
Am-241	0.09 (0.002)	0.17 (0.01)	<0.22	<0.07	<0.10	0.17 (0.01)	0.26*

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* Indicates standard deviation cannot be determined.

TABLE D.7. (contd.)

STATION: CC-3/1 (Bottom)

Isotope	Particulate Filters pCi/liter	Dissolved pCi/liter				Total Dissolved pCi/liter	Total Dissolved and Particulate pCi/liter
		Aluminum Oxide Beds		Resin Beds			
		1st	2nd	1st	2nd		
Sample Wt (g)	20	413	421	191	170		
K-40	0.12 (0.02)	0.38 (0.28)	0.24 (0.24)	0.50 (0.39)	0.58 (0.23)	1.70*	1.82*
Co-60	<0.002	<0.04	<0.05	<0.07	<0.04	<0.20	<0.202
Cs-134	<0.002	<0.05	<0.05	<0.09	<0.06	<0.25	<0.252
Cs-137	0.001 (0.0007)	<0.03	<0.04	<0.07	<0.04	<0.18	0.001 (0.0007)
Ce-144	<0.03	<0.52	<0.53	<0.76	<0.45	<2.26	<2.29
Bi-207	<0.001	<0.03	<0.03	<0.04	<0.02	<0.12	<0.121
Ra-226	<0.005	<0.09	<0.10	<0.11	<0.06	<0.36	<0.365
Ra-228	<0.01	<0.19	<0.24	<0.30	<0.15	<0.88	<0.89
Th-228	<0.005	<0.09	<0.10	<0.13	<0.08	<1.21	<1.22
U-235	<0.01	<0.19	<0.19	<0.30	<0.17	<0.85	<0.86
U-238	<0.03	<0.56	<0.58	<0.63	<0.35	<2.12	<2.15
Am-241	0.07 (0.002)	0.19 (0.04)	<0.14	<0.13	<0.08	0.19 (0.04)	0.26*

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* Indicates standard deviation cannot be determined.

TABLE D.7. (contd.)

STATION: CC-3/2

Isotope	Particulate Filters pCi/liter	Dissolved pCi/liter				Total Dissolved pCi/liter	Total Dissolved and Particulate pCi/liter
		Aluminum Oxide Beds		Resin Beds			
		1st	2nd	1st	2nd		
Sample Wt (g)	16	444	393	186	185		
K-40	0.21 (0.01)	<0.05	1.29 (0.80)	0.19 (0.13)	0.55 (0.25)	2.03*	2.24*
Co-60	<0.002	<0.10	<0.13	<0.02	<0.04	<0.29	<0.292
Cs-134	<0.004	<0.10	0.13 (0.04)	<0.02	<0.06	0.13 (0.04)	0.13 (0.04)
Cs-137	0.002 (0.0005)	<0.10	<0.09	<0.01	<0.04	<0.24	0.002 (0.0005)
Ce-144	<0.03	<0.96	<1.56	<0.23	<0.46	<3.21	<3.24
Bi-207	<0.002	<0.05	<0.09	<0.01	<0.02	<0.17	<0.172
Ra-226	<0.004	<0.15	<0.22	<0.02	<0.06	<0.45	<0.454
Ra-228	<0.01	<0.40	<0.58	<0.08	<0.17	<1.23	<1.24
Th-228	0.01 (0.002)	<0.20	<0.27	<0.04	<0.08	<0.59	0.01 (0.002)
U-235	<0.01	<0.40	<0.62	<0.08	<0.19	<1.29	<1.30
U-238	<0.004	<0.86	<1.29	<0.25	<0.40	<2.80	<2.804
Am-241	0.23 (0.004)	0.30 (0.05)	0.09 (0.09)	<0.06	<0.08	0.39*	0.62*

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* Indicates standard deviation cannot be determined.

TABLE D.7. (contd.)

STATION: CC-3/3

Isotope	Particulate Filters pCi/liter	Dissolved pCi/liter				Total Dissolved pCi/liter	Total Dissolved and Particulate pCi/liter
		Aluminum Oxide Beds		Resin Beds			
		1st	2nd	1st	2nd		
Sample Wt (g)	16	404	390	175	170		
K-40	0.24 (0.02)	0.91 (0.32)	0.10 (0.10)	0.07 (0.05)	0.95 (0.27)	2.03*	2.27*
Co-60	<0.002	<0.05	<0.02	<0.01	<0.05	<0.13	<0.132
Cs-134	<0.004	<0.05	<0.03	<0.01	<0.07	<0.16	<0.164
Cs-137	0.004 (0.0006)	<0.04	<0.02	<0.01	<0.05	<0.12	0.004 (0.0006)
Ce-144	<0.03	<0.59	<0.26	<0.12	<0.52	<1.49	<1.52
Bi-207	<0.002	<0.04	<0.02	<0.01	<0.02	<0.09	<0.092
Ra-226	<0.004	<0.05	<0.04	<0.01	<0.07	<0.17	<0.174
Ra-228	<0.01	<0.21	<0.10	<0.05	<0.20	<0.56	<0.57
Th-228	0.01 (0.002)	<0.11	0.04 (0.02)	<0.02	<0.09	0.04 (0.02)	0.05*
U-235	<0.01	<0.21	<0.10	<0.05	<0.20	<0.56	<0.57
U-238	<0.03	<0.64	0.10 (0.10)	<0.12	<0.43	0.10 (0.10)	0.10 (0.10)
Am-241	0.19 (0.004)	<0.16	<0.05	<0.02	<0.09	<0.32	0.19 (0.004)

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* Indicates standard deviation cannot be determined.

TABLE D.7. (contd.)

STATION: CC-5/1

Isotope	Particulate Filters pCi/liter	Dissolved pCi/liter: Aluminum Oxide Beds 1st	Dissolved pCi/liter: Aluminum Oxide Beds 2nd	Dissolved pCi/liter: Resin Beds 1st	Dissolved pCi/liter: Resin Beds 2nd	Total Dissolved pCi/liter	Total Dissolved and Particulate pCi/liter
Sample Wt (g)	21	393	409	171	185		
K-40	0.23 (0.02)	<0.47	<0.32	0.18 (0.14)	1.15 (0.29)	1.33*	1.56*
Co-60	<0.003	<0.10	<0.02	<0.02	<0.05	<0.19	<0.193
Cs-134	<0.003	<0.10	<0.03	<0.02	<0.07	<0.22	<0.223
Cs-137	0.003 (0.0008)	<0.10	<0.02	<0.02	<0.05	<0.19	0.003 (0.0008)
Ce-144	<0.03	<0.99	<0.22	<0.25	<0.54	<2.00	<2.03
Bi-207	<0.002	<0.05	<0.02	<0.01	<0.02	<0.10	<0.102
Ra-226	<0.01	0.47 (0.04)	<0.03	<0.02	<0.07	0.47 (0.04)	0.47 (0.04)
Ra-228	<0.01	<0.36	<0.11	<0.09	<0.20	<0.76	<0.77
Th-228	<0.003	<0.21	<0.05	<0.05	<0.10	<0.41	<0.413
U-235	<0.01	<0.42	<0.11	<0.09	<0.22	<0.84	<0.85
U-238	<0.002	<0.88	<0.27	<0.27	<0.44	<1.86	<1.862
Am-241	0.10 (0.003)	0.21 (0.04)	<0.05	<0.07	<0.10	0.21 (0.04)	0.31*

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* Indicates standard deviation cannot be determined.

TABLE D.7. (contd.)

STATION: CC-5/2 (Top)

	Particulate	Dissolved pCi/liter				Total	Total Dissolved
	Filters	Aluminum Oxide Beds		Resin Beds		Dissolved	and Particulate
Isotope	pCi/liter	1st	2nd	1st	2nd	pCi/liter	pCi/liter
Sample Wt (g)	25	458	437	201	202		
K-40	0.30 (0.03)	<0.47	2.16 (0.89)	<0.21	1.24 (0.41)	3.4*	3.7*
Co-60	<0.004	<0.03	<0.15	<0.02	<0.07	<0.27	<0.274
Cs-134	<0.004	<0.04	<0.15	<0.03	<0.07	<0.29	<0.294
Cs-137	<0.004	<0.02	<0.07	<0.02	<0.03	<0.14	<0.144
Ce-144	<0.04	<0.31	<1.49	<0.24	<0.69	<2.73	<2.77
Bi-207	<0.003	<0.02	<0.07	<0.02	<0.03	<0.14	<0.143
Ra-226	<0.01	<0.05	<0.22	<0.03	<0.10	<0.40	<0.41
Ra-228	<0.02	<0.16	<0.60	<0.10	<0.28	<1.14	<1.16
Th-228	0.02 (0.004)	<0.07	<0.22	<0.03	<0.10	<0.42	0.02 (0.004)
U-235	<0.02	<0.16	<0.60	<0.10	<0.28	<1.14	<1.16
U-238	<0.05	0.39 (0.16)	<1.19	<0.27	<0.55	0.39 (0.16)	0.39 (0.16)
Am-241	0.08 (0.004)	0.16 (0.02)	<0.22	<0.07	<0.10	0.16 (0.02)	0.24*

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* Indicates standard deviation cannot be determined.

TABLE D.7. (contd.)

STATION: CC-5/2 (Middle)

		Dissolved pCi/liter					
		Aluminum Oxide Beds		Resin Beds			
Isotope	Particulate Filters pCi/liter	1st	2nd	1st	2nd	Total Dissolved pCi/liter	Total Dissolved and Particulate pCi/liter
Sample Wt (g)	17	437	453	199	205		
K-40	0.25 (0.04)	1.78 (0.67)	<1.10	<0.28	0.18 (0.08)	1.96*	2.21*
Co-60	<0.01	<0.11	<0.06	<0.05	<0.01	<0.23	<0.24
Cs-134	<0.01	<0.11	<0.06	<0.05	<0.01	<0.23	<0.24
Cs-137	<0.01	<0.06	<0.05	<0.05	<0.08	<0.24	<0.25
Ce-144	<0.07	<1.12	<0.64	<0.53	<0.10	<2.39	<2.46
Bi-207	<0.004	<0.06	<0.03	<0.03	<0.01	<0.13	<0.134
Ra-226	<0.01	<0.17	<0.12	<0.08	<0.02	<0.39	<0.40
Ra-228	<0.03	<0.45	0.23 (0.06)	<0.20	<0.05	0.23 (0.06)	0.23 (0.06)
Th-228	<0.004	<0.17	<0.12	<0.10	<0.02	<0.41	<0.414
U-235	<0.03	<0.45	<0.23	<0.20	<0.05	<0.93	<0.96
U-238	<0.08	<0.89	<0.69	<0.46	<0.01	<2.05	<2.13
Am-241	<0.01	<0.17	<0.17	<0.10	<0.02	<0.46	<0.47

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* Indicates standard deviation cannot be determined.

TABLE D.7. (contd.)

STATION: CC-5/2 (Bottom)

Isotope	Particulate Filters pCi/liter	Dissolved pCi/liter: Aluminum Oxide Beds 1st	Dissolved pCi/liter: Aluminum Oxide Beds 2nd	Dissolved pCi/liter: Resin Beds 1st	Dissolved pCi/liter: Resin Beds 2nd	Total Dissolved pCi/liter	Total Dissolved and Particulate pCi/liter
Sample Wt (g)	22	434	462	179	164		
K-40	0.36 (0.04)	0.40 (0.29)	1.76 (0.73)	<0.14	0.91 (0.24)	3.07*	3.43*
Co-60	<0.01	<0.05	<0.12	<0.01	<0.04	<0.22	<0.23
Cs-134	<0.01	<0.06	<0.12	<0.01	<0.04	<0.23	<0.24
Cs-137	<0.01	<0.04	<0.06	<0.01	<0.02	<0.13	<0.14
Ce-144	<0.07	<0.57	<1.44	<0.09	<0.43	<2.53	<2.60
Bi-207	<0.01	<0.03	<0.06	<0.01	<0.02	<0.12	<0.13
Ra-226	<0.01	<0.06	<0.18	<0.01	<0.06	<0.31	<0.32
Ra-228	<0.03	<0.23	<0.49	<0.05	<0.17	<0.94	<0.97
Th-228	<0.01	<0.11	<0.18	<0.02	<0.06	<0.37	<0.38
U-235	<0.03	<0.23	<0.49	<0.05	<0.17	<0.94	<0.97
U-238	<0.08	<0.63	<0.97	<0.12	<0.37	<2.09	<2.17
Am-241	0.27 (0.01)	0.17 (0.05)	<0.18	<0.02	<0.06	0.17 (0.05)	0.44*

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* Indicates standard deviation cannot be determined.

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TABLE D.7. (contd.)

STATION: CC-5/3

Isotope	Particulate Filters pCi/liter	Dissolved pCi/liter				Total Dissolved pCi/liter	Total Dissolved and Particulate pCi/liter
		Aluminum Oxide Beds		Resin Beds			
		1st	2nd	1st	2nd		
Sample Wt (g)	15.5	394	443	173	174		
K-40	0.27 (0.10)	<0.31	<0.35	0.73 (0.27)	0.37 (0.14)	1.10*	1.37*
Co-60	<0.001	<0.04	<0.02	<0.05	<0.02	<0.13	<0.131
Cs-134	<0.001	<0.04	<0.03	<0.05	<0.02	<0.14	<0.141
Cs-137	<0.001	<0.03	<0.02	<0.05	<0.02	<0.12	<0.121
Ce-144	<0.01	<0.36	<0.23	<0.50	<0.25	<1.34	<1.35
Bi-207	<0.0008	<0.02	<0.02	<0.02	<0.01	<0.07	<0.0708
Ra-226	0.06 (0.01)	<0.05	<0.04	<0.07	<0.02	<0.18	0.06 (0.01)
Ra-228	<0.004	<0.16	<0.12	<0.18	<0.09	<0.55	<0.554
Th-228	<0.002	<0.05	<0.05	<0.09	0.02 (0.01)	0.02 (0.01)	0.02 (0.01)
U-235	<0.01	<0.16	<0.12	<0.20	<0.09	<0.57	<0.58
U-238	<0.02	<0.41	<0.47	<0.43	<0.25	<1.56	<1.58
Am-241	0.16 (0.01)	0.21 (0.03)	<0.05	<0.09	<0.07	0.21 (0.03)	0.37*

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* Indicates standard deviation cannot be determined.

TABLE D.7. (contd.)

STATION: CC-9

	Particulate Filters pCi/liter	Dissolved pCi/liter				Total Dissolved pCi/liter	Total Dissolved and Particulate pCi/liter
		Aluminum Oxide Beds		Resin Beds			
Isotope		1st	2nd	1st	2nd		
Sample Wt (g)	17	423	439	179	230		
K-40	0.20 (0.04)	<0.47	<0.60	<0.20	0.34 (0.17)	0.34 (0.17)	0.54*
Co-60	<0.004	<0.10	<0.02	<0.04	<0.03	<0.19	<0.194
Cs-134	<0.01	<0.10	<0.03	<0.04	<0.03	<0.20	<0.21
Cs-137	<0.004	<0.05	<0.02	<0.02	<0.02	<0.11	<0.114
Ce-144	<0.051	<0.99	<0.22	<0.42	<0.31	<1.94	<1.99
Bi-207	<0.004	<0.05	<0.02	<0.02	<0.02	<0.11	<0.114
Ra-226	0.01 (0.004)	<0.16	<0.04	<0.07	<0.03	<0.30	0.01 (0.0004)
Ra-228	<0.02	<0.42	<0.11	<0.16	<0.11	<0.80	<0.82
Th-228	0.02 (0.004)	<0.16	0.16 (0.02)	<0.07	<0.06	0.16 (0.02)	<0.18*
U-235	<0.02	<0.42	<0.11	<0.18	<0.11	<0.82	<0.84
U-238	<0.02	<0.89	<0.27	<0.35	<0.34	<1.85	<1.87
Am-241	0.14 (0.01)	0.21 (0.04)	<0.05	<0.07	<0.09	0.21 (0.04)	0.35*

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* Indicates standard deviation cannot be determined.

TABLE D.7. (contd.)

STATION: CC-11 (Bottom)

Isotope	Particulate Filters pCi/liter	Dissolved pCi/liter				Total Dissolved pCi/liter	Total Dissolved and Particulate pCi/liter
		Aluminum Oxide Beds		Resin Beds			
		1st	2nd	1st	2nd		
Sample Wt (g)	16	409	432	190	172		
K-40	0.22 (0.02)	<0.32	<0.34	<0.22	0.18 (0.07)	0.18 (0.07)	0.40*
Co-60	<0.002	<0.02	<0.02	<0.05	<0.01	<0.10	<0.102
Cs-134	<0.004	<0.03	<0.03	<0.05	<0.04	<0.15	<0.154
Cs-137	<0.002	<0.02	<0.02	<0.05	<0.01	<0.10	<0.102
Ce-144	<0.03	<0.21	<0.23	<0.47	<0.09	<1.00	<1.03
Bi-207	<0.002	<0.02	<0.02	<0.02	<0.01	<0.07	<0.072
Ra-226	<0.004	<0.04	<0.03	<0.07	<0.01	<0.15	<0.154
Ra-228	<0.01	<0.11	<0.11	<0.20	<0.05	<0.47	<0.48
Th-228	<0.002	0.21 (0.02)	<0.05	<0.07	<0.02	0.21 (0.02)	0.21 (0.02)
U-235	<0.004	<0.11	<0.11	<0.20	<0.05	<0.47	<0.474
U-238	<0.02	0.21 (0.11)	<0.45	<0.40	<0.11	0.21 (0.11)	0.21 (0.11)
Am-241	0.10 (0.002)	0.16 (0.02)	<0.05	<0.07	<0.02	0.16 (0.02)	0.26*

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* Indicates standard deviation cannot be determined.

TABLE D.7. (contd.)

STATION: CC-11 (Top)

Isotope	Particulate Filters pCi/liter	Dissolved pCi/liter						Total Dissolved pCi/liter	Total Dissolved and Particulate pCi/liter
		Aluminum Oxide Beds			Resin Beds				
		1st	2nd	3rd	1st	2nd	3rd		
Be-7									
K-40	0.25 (0.08)					0.61 (0.37)	0.48 (0.23)	1.09*	1.34*
Mn-54									
Co-60									
Nb-95									
Rh-102									
Sb-125									
Cs-134									
Cs-137	0.004 (0.003)								0.004 (0.003)
Ce-141									
Ce-144			0.11 (0.10)					0.11 (0.10)	0.11 (0.10)
Eu-155									
Pb-210			0.63 (0.45)				0.22 (0.20)	0.85*	0.85*
Ra-226	0.005 (0.004)	0.05 (0.02)						0.05 (0.02)	0.055*
Th-228						0.019 (0.018)		0.019 (0.018)	0.019 (0.018)
Th-232									
U-235									
U-238									
Am-241	0.15 (0.01)	0.12 (0.04)						0.12 (0.04)	0.27*

Blanks indicate activity levels below detection.
* Indicates standard deviation cannot be determined.

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TABLE D.8. Concentration of Radionuclides in the Water of Buttermilk and Cattaraugus Creek Samplings Stations. Results of radiochemical analysis of alpha and beta emitting radionuclides. Values in parentheses are one standard deviation of the propagated counting error.

Station	Particulate pCi/Sample Filters	Dissolved pCi/Sample						Total Dissolved pCi/liter	Total Dissolved and Particulate pCi/liter
		Aluminum Oxide Beds			Resin Beds				
		1st	2nd	3rd	1st	2nd	3rd		
GVC									
Sample Wt., g	10	368.0	390.0		155.0				
Sr-90	<0.0069	33.48(3.48)	64.024(4.50)		*			0.1237 *2,3	0.1237 *2,3
Pu-238	<0.003	<0.003	<0.003		<0.003			<0.00001	<0.00002
Pu-239,240	<0.014	<0.014	<0.014		<0.014			<0.00005	<0.00007
Am-241	29.31(1.38)	228.5(17.37)	*1		*1			0.290 *2,3	0.327 *2,3
Cm-244	<0.0076	0.032(0.03)	*1		*1			0.000038 *2,3	0.000038 *2,3
FC-1									
Sample Wt., g	15.9	426.2	401.0	586.4	159.0	152.6	141.5		
Sr-90	9.48(3.23)	*1	1245.13(69.85)	881.57(49.65)	<0.0149	25.01(16.76)	7.13(5.06)	20.30 *2,3	20.39 *2,3
Pu-238	<0.003	<0.003	<0.003	<0.003	<0.003	0.186(0.058)	<0.003	0.0017(0.058)	0.0017(0.058)
Pu-239,240	<0.014	<0.014	<0.014	0.06(0.01)	<0.014	<0.014	<0.014	0.00056(0.00009)	0.00056(0.00009)
Am-241	0.596(0.085)	0.49(0.08)	0.26(0.03)	0.647(0.178)	1.65(1.42)	0.88(0.12)	0.76(0.14)	0.0441 *2	0.0497 *2
Cm-244	0.049(0.024)	<0.0076	0.01(0.008)	0.166(0.077)	1.87(0.92)	<0.0076	<0.0076	0.0192 *2	0.0197 *2
BC-4									
Sample Wt., g	414.3	461.5	398.9		194.1				
Sr-90	<0.0393	*1	739.17(41.77)		<0.0149			0.868 (0.049) *2,3	0.868 (0.049) *2,3
Pu-238	0.022(0.015)	<0.003	<0.003		<0.003			<0.00001	0.00003(0.000002)
Pu-239,240	<0.014	0.021(0.007)	0.04(0.016)		0.024(0.013)			0.0001 *2	0.0001 *2
Am-241	10.27(0.72)	19.08(2.4)	1.54(0.15)		1.5(0.73)			0.026 *2	0.038 *2
Cm-244	0.069(0.044)	0.11(0.09)	<0.0076		<0.0076			0.0001(0.0001)	0.0002 *2

TABLE D.8. (contd.)

Station	Particulate pCi/Sample Filters	Dissolved pCi/Sample						Total Dissolved pCi/liter	Total Dissolved and Particulate pCi/liter
		Aluminum Oxide Beds			Resin Beds				
		1st	2nd	3rd	1st	2nd	3rd		
CC-1									
Sample Wt., g	15.3	451.0	459.5	442.2	228.9				
Sr-90	<0.0438	20.28(2.09)	36.75(3.90)	25.55(2.31)	<0.6690			0.110 *2	0.110 *2
Pu-238	0.342(0.058)	<0.003	<0.003	<0.003	<0.003			<0.00002	0.00046(0.00008)
Pu-239,240	0.416(0.066)	0.016(0.006)	<0.014	<0.014	<0.014			0.00002(0.00001)	0.00058
Am-241	*1	99.98(9.02)	61.28(8.08)	43.73(2.8)	4.6(0.65)			0.280 *2,3	0.280 *2,3
Cm-244	*1	<0.0076	<0.0076	<0.0076	<0.0076			<0.00004	<0.00004 *3
CC-3/2									
Sample Wt., g	16.0	393.0	448.7		186.0				
Sr-90	<0.0418	12.38(1.75)	42.02(2.91)		*1			0.062 *2,3	0.062 *2,3
Pu-238	<0.003	<0.003	<0.003		<0.003			<0.00001	<0.00001
Pu-239,240	<0.014	0.151(0.051)	0.032(0.014)		<0.014			0.0002 *2	0.0002 *2
Am-241	84.33(7.32)	93.35(6.66)	77.87(4.4)		1.61(0.343)			0.083 *2	0.292 *2
Cm-244	<0.0076	0.042(0.03)	<0.008		<0.0076			0.00005(0.00003)	0.00005(0.00003)
CC-5/2 (Mid-depth)									
Sample Wt., g	17.0	437.0	453.0		199.0				
Sr-90	<0.0393	51.13(3.41)	87.72(5.72)		<0.669			0.177 *2	0.177 *2
Pu-238	<0.003	<0.003	<0.003		<0.003			<0.00001	<0.00002
Pu-239,240	<0.014	<0.014	<0.014		<0.014			<0.00005	<0.00007
Am-241	93.71(5.88)	71.46(4.23)	4.78(0.26)		7.24(1.18)			0.107 *2	0.226 *2
Cm-244	<0.0076	<0.0076	<0.0076		<0.0076			<0.00003	<0.0004

TABLE D.8. (contd.)

Station	Particulate pCi/Sample Filters	Dissolved pCi/Sample: Aluminum Oxide Beds 1st	Aluminum Oxide Beds 2nd	Aluminum Oxide Beds 3rd	Resin Beds 1st	Resin Beds 2nd	Resin Beds 3rd	Total Dissolved pCi/liter	Total Dissolved and Particulate pCi/liter
CC-11									
(Bottom)									
Sample Wt., g	16.0	409.0	432.0		190.0				
Sr-90	<0.041	81.14(5.54)	72.44(6.00)		<0.6690			0.201 *2	0.201 *2
Pu-238	<0.003	<0.003	<0.003		<0.003			<0.00001	<0.00002
Pu-239,240	<0.014	<0.014	<0.014		0.046(0.027)			0.00006(0.00004)	0.00006(0.00004)
Am-241	53.9(3.08)	82.87(9.74)	5.2(1.38)		*1			0.115 *2,3	0.186 *2,3
Cm-244	<0.0076	<0.0076	<0.0076		*1			<0.00002	<0.00003

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*1 Sample lost during analysis

*2 Standard deviation cannot be determined

*3 Unreliable minimum value due to missing analysis results

TABLE D.9. Tritium Activity in the Water of the Buttermilk and Cattaraugus Creek Sampling Stations

Station	Tritium Unit	pCi/liter(a)
BC-1	65.004 ± 10.385	209.18 ± 33.42
BC-4	257.927 ± 13.280	830.01 ± 42.73
CC-1	52.436 ± 10.789	168.74 ± 34.72
CC-3 Sta 1-Top	100.360 ± 10.854	322.96 ± 34.93
CC-3 Sta 1-Bot	120.865 ± 11.758	388.94 ± 37.84
CC-3 Sta 2	119.162 ± 11.116	383.46 ± 35.77
CD-3 Sta 3	328.107 ± 16.149	1055.85 ± 51.97
CC-5 Sta 2-Top	94.161 ± 11.367	303.01 ± 36.58
CC-5 Sta 2-Top-M	83.432 ± 11.214	268.48 ± 36.09
CC-5 Sta 2-Bot	113.474 ± 11.648	365.16 ± 37.48
CC-5 Sta 3	113.474 ± 11.648	365.16 ± 37.48
CC-11	92.492 ± 11.343	297.64 ± 36.50
FC-1	1060.886 ± 28.894	3413.93 ± 92.98
Background	64.408 ± 9.693	207.26 ± 31.19

(a) t-1/2 = 12.35 years and 1 T.U. = 3.218 pCi/liter

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A field sampling program was conducted on Cattaraugus and Buttermilk Creeks, New York during September 1978 to investigate the transport of radionuclides in surface waters as part of a continuing program to provide data for application and verification of Pacific Northwest Laboratory's (PNL) sediment and radionuclide transport model, SERATRA. Suspended sediment, bed sediment, and water samples were collected during low flow conditions over a 45 mile reach of stream channel. Radiological analysis of these samples included primarily gamma ray emitters; however, six alpha and beta-emitting radionuclides were analyzed using radiochemical methods. The Nuclear Fuel Services facilities are a possible source of two gamma-emitting radionuclides: 1) Cesium-134, and 2) Cesium-137. The principal beta-emitter found was Strontium-90. Elevated levels of both Cesium-137 and Strotium-90 were found at the sampling stations immediately downstream of the facilities. Based on downstream trends of activity levels of other radionuclides, the Nuclear Fuel Field Services facilities may also be a possible source of Plutonium-238 and 239, 240, Americium-241, Curium-244, and Tritium. This field sampling effort is the second of a three phase program to collect hydrologic and radiologic data at three different flow conditions.

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